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NATIONAL SCIENCE FOUNDATION AUTHORIZATION

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BEFORE THE

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SCIENCE, TECHNOLOGY, AND SPACE

OF THE

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SCIENCE, AND TRANSPORTATION

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NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MARCH 3, 1983

U.S. Senate,
Committee on Commerce, Science, and Transportation,
Subcommittee on Science, Technology, and Space,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:30 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

Staff members assigned to those hearings: Cheryl Coodley, counsel; and Steven H. Flajser, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator Gorton. Welcome to the subcommittee's hearing this morning on the plans and programs of the National Science Foundation for fiscal year 1984. This will be the first of 2 days of such hearings, the second of which will occur on March 9.

The National Science Foundation is unique among Federal agencies. Its primary mission is to support fundamental research in virtually every field of science and engineering. The Foundation funds projects ranging from the development of mathematical models to explaining how individual cells organize into living animals, to the identification of distant galaxies which offer clues as to the origin of our universe.

In Washington State, for example, NSF grantees work on projects which range from a study of the structure and composition of the Earth's crust around the Mount St. Helen's area to a study of the relationship of ocean salinity and temperature to the biological life cycle of marine organisms.

For the upcoming year I am delighted to see that the proposed budget for the National Science Foundation provides real growth in almost all the major programs of the agency. With an overall increase of about 18 percent for the Foundation as a whole, and even greater increases in specific high priority areas such as mathematics, materials sciences, mechanical engineering, plant biology and ocean drilling, I believe that NSF will be able to accelerate significantly its contribution to scientific progress.

We will be exploring a variety of issues today with witnesses from the administration and National Science Board and, on March 9, with witnesses from academia and industry.

Some of these issues include: Priorities in funding of NSF programs; the prospects and possibilities for stable funding of research, including identification of mechanisms for funding research other than the Federal Government; consistent with that issue, the roles of industry, academia and the Federal Government in funding basic research and research and development; and the initiatives of the Foundation in instrumentation, opportunities for women and minorities in science, in the international arena, and in support of faculty research at predominantly undergraduate colleges.

We are looking forward to hearing from each of our witnesses on these and other issues of great importance to the scientific health of the Nation.

Senator Heflin, do you have an opening statement?

OPENING STATEMENT BY SENATOR HEFLIN

Senator HEFLIN. Yes, Mr. Chairman.

I would like to say that I look forward very much to my new assignment as ranking Democrat on the subcommittee, and I look forward to a close working relationship with you, Mr. Chairman. I believe we both share the view that science and technology play a very important role in all aspects of American life.

In his state of the Union message, President Reagan said it very well. He talked about the importance of science and technology in rebuilding our economy and maintaining our national security. They certainly can do that and also help in providing good health care, efficient transportation, environmental protection and generally improving the standard of living of all people.

With the Commerce Committee's broad responsibility in the area of science and technology, it seems vital we review the National Science Foundation programs. I support your efforts in holding these hearings. It gives us an opportunity to review the vitality of this Nation's basic research effort, particularly in the universities. We also will be able to evaluate efforts in science and engineering education.

I think the President's budget for NSF is a healthy one. There are increases to cover all areas of effort. The total increase in NSF is 18 percent, and the increase in basic research for all Federal agenices is 10 percent. These increases should help our universities, which in turn should help the Nation. I congratulate Dr. Keyworth and Dr. Knapp for being persuasive with the OMB.

If I have any general questions about the budget, they would deal with two areas: (1) The relationship of the NSF budget and to other R&D agencies, and (2) within the NSF budget, the priority given increases in research versus investment in education.

I look forward to hearing the testimony of our witnesses. Thank you, Mr. Chairman.

Senator GORTON. We also have an opening statement from Senator Hollings which will be included in the record at this point.

[The statement follows:]

OPENING STATEMENT BY SENATOR HOLLINGS

Mr. Chairman, the NSF is a very unique Federal agency. It is the only one that has as its sole responsibility the support of non-medical basic research. It serves as the life blood of our university community, and a number of times an NSF grant supported the research efforts of our Nobel Prize winners.

NSF is also of major importance to our young people who wish to pursue careers in science and engineering. Through research fellowships and assistantships, this nation's talented youth are able to obtain necessary support. This support is critical.

Unfortunately, support of our youth has not been enough. This Administration does not seem to place a great deal of priority on NSF's general science and engineering education programs. When they came into office, they tried to abolish these programs altogether; they did manage to demote them from a directorate to a division program. They chopped the budget from approximately $100 million to $15 million in fiscal year 1982. Only recently, and after much pressure from Congress, where numerous bills have been introduced, has the Administration revised their thinking. The fiscal year 1984 budget request still does not come close to meeting Federal responsibilities. I hope this Committee will be active in correcting these deficiencies.

On the research side, NSF has done quite well. An 18-percent increase is quite significant, particularly when all research areas would benefit. The scientific and engineering community must be quite pleased. They've had to deal with high inflation, faculty shortages and obsolete equipment. They would be even more pleased if there was some stability of support in future years. I would be very interested in seeing projections for future years.

The importance of NSF's 18 percent increase is even more significant when you compare civilian vs. defense R&D increases. Let's look at just a few figures. Defense related R&D programs were funded at a level of $17.8 billion in fiscal year 1981. Comparable figures for fiscal years 1982, 1983, and 1984 are $22.1 billion, $24.9 billion, and $31.8 billion. This amounts to a 79 percent increase! Contrast this with funding for civilian R&D. In fiscal year 1981 it was $17.2 billion. For fiscal years 1982, 1983, and 1984, it was $14.3 billion, $14.0 billion, and $14.0 billion, respectively. This amounts to a 19 percent decrease. Put another way, since fiscal year 1981, the civilian portion of total R&D has decreased from 49 percent to 31 percent of the R&D budget, while defense has increased from 51 percent to 69 percent of the total. Given this Administration's priorities, it is vital that we support NSF's budget to maintain some sense of balance.

Mr. Chairman, finally I would like to take this opportunity to compliment you on your willingness to schedule these hearings. I believe it was an oversight several years ago not to place NSF jurisdiction within this Committee. NSF clearly is a science and research agency, not an education agency. Previous suggestions that we share jurisdiction seem quite reasonable to me. I support you and Senator Packwood in your efforts.

Senator **Gorton**. We will begin our witnesses with Dr. George Keyworth, Director of the Office of Science and Technology Policy. Dr. Keyworth, you are welcome and you may proceed.

STATEMENT OF DR. GEORGE A. KEYWORTH, SCIENCE ADVISER TO THE PRESIDENT AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Dr. **Keyworth**. Thank you, Chairman Gorton.

It is my pleasure to present an overview of the administration's science policy and how it guided the preparation of the President's proposed R&D programs for fiscal year 1984. I hope this perspective is useful in your consideration of the proposed National Science Foundation programs.

Federal science policy has changed substantially in the past few years, and Federal R&D programs reflect those changes in profound ways. As an immediate example, I do not think anyone would have predicted 2 years ago that you would be looking at the kinds of NSF programs being presented now. Let me try to indicate how those priorities came to be.

One of the significant changes in this administration is that science and technology functions do not exist independent from the rest of Government. They are integrated into the planning, analytical, and decisionmaking processes within the White House. My own role is an adviser who brings scientific and technical perspective to issues before the President.

Please do not misunderstand. There is no question that we have to maintain and strengthen the health of our science and technology enterprise as a national resource. But at the same time we have to make sure the Nation gets the best possible return on its Federal investments in science and technology.

Mr. Chairman, in your invitation you asked me to comment on the administration's vision of the future of basic research. I would say unequivocally that American science today contains many, many areas of research that are ripe for profound intellectual advances. The knowledge revolutions are continuing unabated, even accelerating, and our hard choices are choosing from among many, many opportunities for Federal support. So that idea of intellectual opportunity is the first criterion we have used in putting together our Federal programs in R&D.

Second, R&D provides at least two tangible benefits to society. One is new knowledge, and we are determined to use it better to stimulate greater interaction of academic, Federal, and industrial scientists and engineers and to make sure the best R&D is supported well enough to permit rapid progress in developing new ideas that lead to technological innovation.

But the second benefit is in education. As total U.S. R&D grows, our Nation's industrial and economic progress will be increasingly dependent on the availability of trained science and technical personnel. So we also have to derive educational and training advantages from Federally supported research.

One of the best ways is through university research in which students participate. Federal programs must make sure that the academic research community is treated fairly in competition with other research performers.

The third criterion is the appropriateness of the role of the Federal Government in R&D. We have continued to shift the Federal role away from demonstrations of technology and back toward basic research and noncommercial development.

How, then, are our major national goals affected by our R&D policy? Defense is obviously a major element of the overall R&D budget. This country relies heavily on maintaining a technological advantage over our adversaries rather than trying to match up in terms of troop strength and deployment. Fiscal year 1984's growth in defense R&D is largely a remedial and necessary investment to restore the technological lead that was eroded during the 1970's.

The other concern is how Federal investment and leadership in R&D can contribute to economic progress. Throughout the budget, the common thread is our emphasis on basic research to fuel new technologies and on the academic institutions that produce the trained personnel to drive our industrial growth.

In spite of large amounts of Federal funding for basic research over the past 20 years, many of our universities are in poor shape, at least in the physical sciences and engineering. This is partly because so much of that Federal support has gone to nonacademic institutions, such as Federal laboratories.

Most universities have become less attractive places to pursue research careers in those fields. They suffer from poor equipment and poor instrumentation. Because salaries for young faculty are too low to attract many new Ph. D's in this deteriorating research environment, many forgo what not many years ago would have been their preferred career choices.

Education is the critical problem underlying the future of our entire civilian and defense R&D capabilities. This accounts, to a large extent, for our emphasis on funding of research through NSF and other university-oriented programs. For example, next year NSF basic research grants will support some 10,400 graduate students, who will join the S&T industrial personnel base needed for the end of the decade and beyond.

There are other serious problems in education, as you know, and throughout much of the past year we have been consulting with professional groups and universities about them. The result is several new programs to address what we feel is the most critical problem—the inadequate supply of new junior engineering and science faculty in universities and the shortage of qualified secondary school science and math teachers.

We expect this to be a pivotal year for Federal R&D. The administration's science and technology addresses critical needs in our society. We are anxious to work with the Congress to set the country on a productive course to make the best possible use of the resources and potential of our universities, Federal labs, and industrial enterprise.

Mr. Chairman, this concludes my summary and I would be pleased to answer any questions.

Senator GORTON. Thank you very much, Dr. Keyworth. We are, of course, delighted to hear that NSF has been given such a priority in a year in which the emphasis has been on restraint.

I do have a couple of questions, however, that are related to one another. Can you give us an insight into the administration's plans either to identify a stable source of funding for basic research or, as an alternative, what its attitude is likely to be in future years? Is this a one-shot proposition or are we taking seriously a long-range commitment to basic research?

Dr. KEYWORTH. Mr. Chairman, as I am sure you well know, that has been a major concern for many years in the support of basic research. Let me answer both of the portions of that question.

First, it is absolutely essential that we clearly delineate the role of the Federal Government in R&D and that, in effect, we treat the support of basic research, the support of tomorrow's talent, as a Federal trust. And by clearly delineating the Federal role and the Federal responsibility there, I think we can maintain strong support in a bipartisan manner for years and perhaps generations to come.

The recent fluctuation in the development area has tended to divert attention from this area of Federal trust and more into what I would characterize as intervention in the marketplace and intervention in industrial R&D.

Second, I think our administration will enthusiastically support a multiyear effort to try to strengthen our universities and our overall source of tomorrow's talent.

Senator GORTON. Is there a clear distinction in your mind and in your program between basic and applied research and, if so, could you articulate that distinction?

Dr. KEYWORTH. That distinction is always a little fuzzy, but I think we clearly can focus upon basic research in the National Science Foundation and the Office of Energy Research, NASA, and even in DOD as primarily motivated to training talent and to pushing forward the frontiers of science—not to achieve a specific goal.

Now in applied research, of course, the span is much, much broader. We necessarily have emphasized disciplinary areas such as materials science as areas that are very strongly needed by America's industry. But I emphasize that there is always a fuzzy distinction.

The National Science Foundation, whose primary responsibility is basic research, definitely pursues a considerable effort in applied research. But, yes, we have tried to clearly delineate the two and we have specifically tried to delineate what we feel to be the appropriate Federal role in applied research itself.

Senator GORTON. What do you see as the responsibilities of industry, government, and the university, or how do they differ in their responsibilities for basic research?

Dr. KEYWORTH. Well, as we have discussed in the past, we have reached a deplorable situation today. Our Nation possesses, without a doubt, the world's greatest basic research enterprise; we are the Nation that pushes forward most radically to produce new knowledge in science. But although we possess this capability, our ability to pursue advanced technology is compromised by the fact that our academic institutions, our Federal research centers, and our industrial research centers lack good communication—and they lack solid overlap.

We need the involvement of the industrial sector—a very much revitalized industrial sector, I might add, in face of today's competition—in the process of priority-setting, in the process of directing how Federal research funds are spent. And the best way to do that is with an active, involved, participatory role of industry.

And we are trying many new mechanisms to bring industry closer to this, both in terms of new facilities and in encouraging means for them to get more involved in the direction of both the Federal laboratories and academic institutions.

Senator GORTON. One of the few areas in the proposed NSF budget which does not have any increase is social sciences. Why is the administration more skeptical about research in that field than it seems to be about other areas?

Dr. KEYWORTH. We believe that much of the work that the National Science Foundation has supported in social sciences was—let me just say was not of the highest priority amongst the National Science Foundation activities. Now what we have paid considerable attention to is trying to preserve a strong basic disciplinary activity and, perhaps even more important, a basic capability to make certain that the required data base would exist to support a host of Federal decisionmaking.

We have been, if you wish, discriminatory in where that support has gone, but at this point, in forming the fiscal 1984 budget, we did not feel that the social sciences area was in any way suffering in a measure comparable to the physical and engineering sciences.

Senator GORTON. Could you state for us the relationship between or among NSF, NSB, and OSTP in setting science policy for the Nation, and the role of OSTP in preparing the budget?

Dr. KEYWORTH. Certainly. I think, first of all, the evolution of policy frequently happens when one is unaware of it happening. Certainly the National Science Board and I have met several times, plus members of my staff and I have spent an enormous amount of time with the Director and other members of the National Science Foundation.

We have jointly been addressing and trying to identify where the fundamental problems are, why our great U.S. research enterprise does not necessarily reflect itself in our ability to introduce new technologies to the marketplace. And in the course of deliberating these questions, we have come up with a number of thrusts that, in turn, represent science policy as implemented in the budget.

Certainly we have taken an active role in working with the Foundation and the Office of Management and Budget in formulating the fiscal year 1984 NSF budget, just as we did in 1983. But I must stress that there has been a very, very close communication between us all; hardly a day goes by when Dr. Knapp and I, for example, do not find ourselves either in the same office or on the telephone discussing the best ways to crack certain problems.

Senator GORTON. Could you answer the budget half of my question for me—your role in setting this budget?

Dr. KEYWORTH. We were definitely very active in working with OMB in preparing this budget and in presenting it to the President.

Senator GORTON. Do you think that you personally had a significant impact on OMB's views in this respect?

Dr. KEYWORTH. I cannot speak for OMB, but I think it is possible.

Senator GORTON. You stated a number of times and in a number of places, Doctor, that the United States cannot expect to be No. 1 in all scientific disciplines. If that is the case, what is your own set of priorities and ideas about areas of intellectual opportunity? Where do you think we can and must lead, and what kind of change in our own research priorities does that imply?

Dr. KEYWORTH. First of all, let me specify a few, although I may miss some. I certainly think that the fields of high-energy physics and the entire host of material sciences, astronomy and astrophysics, and plant biology are rapidly moving and intellectually exciting areas of science.

I believe that the entire spectrum of biomedical sciences is very important, with particular attention on neurphysiology and, of course, molecular biology. These are amongst the most exciting areas where I believe the United States should expect to be the world's leader.

But one of the reasons why I have made this statement is because the U.S. science enterprise has been somewhat more insulated or isolationist than most other major nations. I think the time has come for us to recognize that we should be excited when major advances are made elsewhere, such as the observation of the W particle in Switzerland a month ago; we should not say, gosh, if only that could have been an American observation.

We are not the only developed nation in the world. We should cooperate internationally in joint ventures. The scientific community in the United States is very much an international community, but I believe that we in Government should address ourselves to trying to improve the mechanisms and the environment for even more international cooperation.

Senator GORTON. Are we in a position to utilize that cooperation, at least to the extent that it involves the free world, so that if something developed in Europe or in Japan it would become a part of our own scientific base?

Dr. KEYWORTH. Very much so. The flow of information throughout the entire spectrum of basic research disciplines moves at about the speed of light. Although I do not know this for a fact, I suspect that when the scientists involved first became reasonably certain about their evidence for the W particle, their counterparts in the United States and elsewhere knew it via the telephone and satellite within hours.

There is a total, free flow of information, and it is absolutely essential to the health and vitality and creativity of the basic research enterprise.

Senator GORTON. And it flows in both directions—from us and to us?

Dr. KEYWORTH. In basic research it flows in both directions equally.

Senator GORTON. Senator Heflin?

Senator HEFLIN. I have been hearing a good deal from engineering schools that there is a real problem in getting the bright students to go on and pursue graduate studies toward the Ph. D. Business today needs engineers. The incentives to go into the private sector are so large that it takes a person who has to have a real desire for a graduate degree to pursue it. And this is a problem that exists throughout the entire country.

In other areas, as we move toward more high technology, more science matters, and this may create problems in other aspects of our academic life. Is any program being devised by which to try to give an incentive that we will have teachers in engineering and in science 15, 20 years from now?

Dr. KEYWORTH. Senator Heflin, you have addressed what I believe to be the central problem that lies before our science and technology enterprise and the central problem that we have attempted to address in our budget in a host of ways—tomorrow's talent.

The very, very serious requirement for more engineering Ph. D's who will become teaching faculty is, I think, an absolutely critical problem. Moreover, as we experience economic growth, much as a result of high technology, this need will become more dire.

What we are trying to do is take carefully thought out and directed steps toward meeting this problem. We have introduced a program in the National Science Foundation, for example, to give awards, as contrasted to grants, to promising young people to, if you wish, entice them into engineering faculty positions. It is a very generous, very prestigious program, and I believe that it is important in that it recognizes that potential young faculty frequently have not mastered the art of grant acquisition.

They do not know the hallways and corridors of Washington. This program will involve selecting individuals for their promise and giving them 5 years of up to $100,000 a year support for their research. This was, I assure you, the very first problem in the area of science and engineering talent that we addressed in the course of the last year.

But we must realize that the biggest role that the Federal Government plays is in the entire support of basic research. Next year we will spend more than $3.5 billion in the support of basic research and academic institutions, and at least half of the motive and the benefit for the American people in that investment should be in the supply of talent that is produced.

This is exactly why I believe that our administration and future administrations will continue to provide a heavy emphasis on this Federal trust, because it is the source of our critical talent for tomorrow.

Senator HEFLIN. Now you make a distinction between grants and awards. I am not familiar with the basic nomenclature and the technical differences. On an award basis, is this something that is granted as a result of an accomplishment?

Dr. KEYWORTH. A grant is awarded on the basis of the quality of the proposal and its pertinence and the reputation of the people behind it. But with very young people right out of graduate school, for example, or at the end of their graduate career, it is very difficult for them to provide the same, let's say, quantity of credentials and for them even to know how to write the kind of proposal that is best received.

So we intend to establish a mechanism with much involvement from the private sector and the National Academy of Sciences and elsewhere by which we select promising young people—based upon faculty recommendations and the general perception amongst their peers—and award them as individuals for the first 5 years of their professional careers as faculty members. So they are awards to individuals rather than research contracts.

Senator HEFLIN. Will this be fairly universal in the academic community? There are those that I have discussed this problem with that fear an MIT or an elite educational approach toward this, which would not take care of the engineering faculty of the future at the University of Washington, or the University of Alabama or some other place. Now, is this your concept of awards? Will it have, as a part of it, the right for schools, universities, colleges, to participate throughout the entire United States?

Dr. KEYWORTH. Actually, Senator, I believe that the mechanism even more will support an individual at a lesser known university because of this award process as opposed to a grant process. Dr. Knapp and I have frequently discussed the detailed objectives of this program, and I believe that you will see a very broad distribution of support across both the leading institutions and those smaller institutions that are rapidly developing strong efforts in engineering. And I think you will be encouraged by this emphasis upon assistant professors, rather than on senior tenured faculty.

Senator HEFLIN. Are there any programs dealing with the relationship of educational institutions, consulting scientists and the private sector and Government; a program designed to integrate, to some degree, or at least to have an interchange of consulting scientists and engineers with educational institutions largely as resources for specific areas, and then with the Government and then with the private sector?

This appears to me to be an area that can stand some attention and some beefing up as we go along in order to make it more effective.

Dr. KEYWORTH. As I have said many times, I think this has got to be one of the two central objectives of our approach to basic research. We have tried to introduce mechanisms by which industry and industrial R&D leaders are actually involved in the process of priority-setting. We will actually establish, for example, boards of oversight over many of our Federal laboratories. We want to break down what I have frequently called this chasm between our excellent academic research centers and the needs of industry. I think this is absolutely essential.

We have tried to do some of this in specific programs, but we are all—the executive branch, the legislative branch, and the entire scientific and industrial community—going to have to work together to assure that we can create and permit as many mechanisms as possible by which this can be encouraged. It is a flaw, I believe, in our system that has developed in the last 20 or 25 years.

Senator HEFLIN. I constantly run into the massive structure of the Federal Government, it's bifurcated and duplications exist. People pursue the same thing without coordination or direction. Do you have in mind any procedures that you would establish which would insure that each agency knows what all other agencies are doing with respect to common research areas, particularly in such technologies as material processing, lasers, particle beams and microelectronics?

Dr. KEYWORTH. Mr. Senator, I would be more than presumptuous if I were to tell you that I knew all of the answers or that this problem had been solved. We are trying to establish a very clear science policy that the various departments and agencies can treat as guidelines. We are using the so-called Federal Coordinating Committee on Science, Engineering and Technology as a means to do this. But I think a clear delineation of goals and objectives that can be supported in a bipartisan fashion is essential. That is what I am trying to focus on and is why I am trying to specify very clearly the importance and the Federal trust nature of basic research.

There are areas—microelectronics is one—that are very heavily dominated by Department of Defense activities and Department of Defense needs. I do think, incidentally, that the so-called VHSIC program in DOD is a very, very successful program. I must admit that I only regret that there is only one of those programs of such caliber and quality.

As I remember, nearly 2 years ago you and I discussed at this same table, these serious concerns about the Federal Government's ability to coordinate our high-energy laser development activities. I can only assure you that although it is a difficult problem, I believe we are making headway, and I hope that it is not another 2 years before I can speak even more positively.

The other area you mentioned, materials science, is immensely broad and critically important to American industry and defense. I do think we can speak with some higher confidence in that area. This Nation is very good in materials science. I think the very large thrust that we are putting into the National Science Foundation and into the Office of Energy Research must be sustained, because the need is so enormous. American industry has only really begun to appreciate the opportunities for materials advances, just as it is only beginning to appreciate the effects of robotics.

Senator HEFLIN. I hope we are going to have some more hearings on lasers. This field is moving rapidly. We hear that the Russians are particularly active in this field, and it is an area that I think the United States has got to direct more attention to.

Now, at this particular time we may be left at the starting gate. Of course, I know that we have a great deal going on in the military and other things, but it is an area that we may be asking you in some hearings, if you will, to give us some information relative to it. Some of it would obviously have to be in classified hearings.

But it is an area, again, that it seems to me that America has to be moving forward.

Dr. KEYWORTH. Senator, I would be, first of all, happy to do that. Moreover, let me state candidly that I am afraid the field worldwide is moving faster than the host of programs, not terribly well-guided, that we have today. So I share your concerns.

Senator HEFLIN. I want to ask you some questions and maybe come back if time permits. The Department of Defense's research and development budget increased this year by 29 percent. The National Science Foundation is increasing by 18 percent, yet in the research and development budget of NASA, the increase is only 3.9 percent. Why is NASA getting such a small increase in R&D moneys, and aren't they one of the best agencies to help keep the U.S. technological leadership that we have acquired in the past?

Dr. KEYWORTH. I think the answer to that question really encompasses the basic tenets of our science policy. We have focused first and foremost on adequate and highest possible quality talent.

The basic research component in NASA, the part that really influences the generation of new talent, went up almost 14 percent. Now, the overall modest increase or real decrease in R&D simply represents the fact that the Shuttle, which has been in an intense stage of development for some 10 years, is approaching an operational phase. And, incidentally, there also is an artifact of a slight transition of what we are calling R&D and what we are not calling R&D in there.

But the emphasis on basic research in NASA and upon exploiting the Shuttle for new space science and new space research, exploration, and applications is very real. There are substantial new missions in NASA such as the Venus mapper, for example, and the gamma ray observatory.

We have paid enormous attention to exploiting the Shuttle rather than to developing either more Shuttles or the next phase of the Shuttle, because the Shuttle is not yet operational. We are now at the culmination of 10 years of R&D, and that is what the budget reflects.

Senator HEFLIN. All right. So there are, of course, areas in materials processing with a great future, and they need I think a good deal of basic research, as well as other space efforts. We hope that you give careful consideration to our space program as we move forward at this particular time.

I think that it is all right now. I have some other questions later, if time permits.

Senator GORTON. Thank you. Senator Lautenberg?

Senator LAUTENBERG. Thank you, Mr. Chairman. Dr. Keyworth, it is nice to meet you. You have such an important responsibility in our Nation at a fairly critical time, I think. Based on the presentation I have heard you make, you are someone well equipped to manage that function.

Part of my position here is that of kind of a new recruit, and there are some things that I may ask that seem a little basic, certainly not in terms of basic research, but elementary perhaps. Forgive me if that is the case, but I just want to understand a couple of things. And in the process of determining an authorization, I guess this is the best way to shape policy, isn't it? I mean, the budget is what determines all so often what the ultimate direction is.

I would like to pursue some basic issues about the role of Government in the promotion of science and technology. The administration has made it clear that it believes that the role of the private sector is to pursue demonstration programs in testing and near-term technological development. You said in your remarks, we have continued to shift the Federal role away from the demonstrations of technology and back toward its appropriate role of basic research and noncommercial development.

I certainly share the view that Government has a critical role to play in supporting basic research. If the Government does not provide the necessary support, a lot of work just will not be done, and we will not know what happened with those missed opportunities. But we cannot minimize the costs associated with the development of applied technologies. For even when the research has brought us all to a point where the testing can occur, private industry just often cannot handle the high costs associated or the high risks. And they may not take the plunge by themselves.

Does Government, then, also have a critical role to play in supporting the testing and application of technologies? For instance, I think the Japanese Government has played a major role in that connection in concert with industry. Aren't some of our industries on the defensive as a result of that?

Dr. KEYWORTH. That is an overwhelmingly complex question, if you follow its implications. It comes to the very core of the Nation's industrial competitiveness—an issue that I do not believe anyone has fully explored at this point because it is rapidly changing.

Let me go back to the beginning. I say clearly that I believe the Federal Government should not be involved in demonstration that industry can clearly do. That is a black and white question position. But when it comes to the interpretation, issue by issue, frequently the issue is grey.

Let me offer you an example—the area of aeronautics research. Clearly if we were starting a new aircraft industry in the United States today, the Federal Government might have a somewhat different role than it presently does in support of the aeronautics research. But the fact is, this is a critical industry. Aircraft are our second largest export and our largest manufactured export. That industry's health depends critically on the aeronautic research capabilities in NASA.

After extensive review that took us nearly 8 or 9 months, we as an administration decided to support very strongly this critical Federal role in aeronautics research, some of which is in the demonstration arena. It is a judgment that had to be exercised.

Now, the same thing, unfortunately, holds true in trying to analyze the entire question of industrial competitiveness. There is no question that many American corporations are being seriously threatened by the Japanese. Some of them are even, in some cases, being driven under. There is no question that the Japanese system is very different than ours. The Japanese methods for capital formation, banking, et cetera, represent a very different "free enterprise climate than ours.

The Federal role is going to have to be very clearly and carefully thought out in future years, and it is going to be evolving. I think we made a fundamental mistake in the way we approached the energy problem after the Arab oil embargo. It hurt the American R&D and scientific enterprise seriously in many areas. And I think we are all very much reacting to that.

Clearly, applied research is very important to American industry. The President is in the process of establishing a Commission on Industrial Competitiveness composed of America's top academic and industrial leaders in R&D. We are going to address the exact question of an arena of generic but applied research: What the Federal role is, what industry can do better, and how the national and Federal laboratories can be used to, if you wish, bridge the link.

And you are right. It is not a question of the Federal Government way over here working on esoteric research, and industry here trying to introduce materials advances into our automobiles. There is a great region in between, and the Federal Government cannot categorically or ideologically say we do not belong here. Judgment is required.

Senator LAUTENBERG. Particularly when so much of our business opportunity in this country lies in the small business sector, they just do not have the means to get out and do the demonstration projects and do the general market testing that is required. And somehow or other, we have got to be able to find a way to help this innovation, this creativity that does come out of the small business sector. The large companies, when you talk about aircraft, the aircraft industry, you are talking about quite a different group.

There is an area of overlap. You said something in your remarks about that very often disparate elements are not communicating, I think. Would you advocate some national central coordinating body to do that, to make sure that each element of our research society, academic, business, and so forth, is communicating? That does not sound like it is consistent.

Dr. Keyworth. There are many mechanisms in which the communication can take place. What we have to do, I believe, is to look carefully at the impediments. The impediments are, in some cases, in the patent world, for example. In other cases there has been no effort to provide direction for the way basic research funds have been allocated with respect to the needs of American industry.

And that is why I have addressed bringing industry more and more into the process. There is no quick solution. What we have to do is nurture, cultivate, and encourage a fundamentally different environment.

If I may address on the first comment you made, I think we all agree that small businesses are the source of greatest growth. They are also a source of something very strong that I will call uniquely American. As we try to address the challenge of—and in too many cases emulate—Japan, we must remember that the entrepreneur is an American. This entrepreneurial spirit is not commonly found in Japanese industry—the young, dynamic risk-taking entrepreneur who mortgages his home and, for all I know, his family to get an idea going. That spirit must not be crushed, and it must not be crushed by the welfare mentality, if you wish.

Senator Lautenberg. I am sorry you used that last sentence in your remarks, because certainly I do not see that kind of relationship. I am a product of American opportunity and entrepreneurship in the purest sense. I was in part founder not only of a company, but an industry, an industry today that does over $20 billion a year in revenues in computer services.

Entrepreneurs are a precious commodity in this country, and we have got to continue to fertilize and nurture and inspire that kind of development.

As a matter of fact, off the subject, for a moment, Mr. Chairman, I think there is a problem with some of the business schools in our country. I am on the board of one, and that one is an exception, of course. There is not effort enough directed toward entrepreneurship. They rather emphasize corporate management, and we see this constant direction toward bigness.

Back to the subject. I am sorry.

I come from New Jersey, and we have one of the finest basic research institutions in the country in the private sector in Bell Laboratories, and discoveries there have changed the whole face of the world, certainly, in the communications area.

You did not mention communications in any of the branches, as I remember, of development. You talked about the molecular and biomedical research and things of that sort. Do you think that we are staying abreast in terms of basic research? Is Government lending any hand to that through the National Science Foundation or others?

Dr. Keyworth. Senator, I think we are very well positioned, and I hesitate to do this, but I am going to have to address the semantics here. Bell Labs, I would even go further and say, is probably the world's greatest industrial laboratory. But only a very small fraction, if I recollect, in the 10-percent realm, of Bell Laboratories actually addresses generic, basic research.

Communications research is really applied research. When the Federal Government supports materials science, for example, it is really addressing research of importance to the communications industry, as well as to the microelectronics industry.

And when we support fundamental mathematics, we are trying to support advances and new talent in areas that will fuel computer sciences, for example. So we are really dealing here with the definitions of basic research versus applied research. At Bell Labs, for example their basic research is conducted in areas of solid state physics.

Senator Lautenberg. Impressively done, of course, and vital to the functioning of our science community all together, and there are very few Bell Labs around the country.

I was pleased to see the administration request for the increase in the National Science Foundation funding. To the extent that your advocacy helped, you certainly are to be commended, but there are trends in Federal support for R&D that I think are slightly disturbing. That is the bias in favor of military R&D.

And before we are too encouraged by administration proposals to increase research and development, should we look further to where the money is going? Defense Department R&D would go from $20 billion in fiscal year 1982 to $30 billion in fiscal year 1984, a 50-percent increase, while other R&D in this same period would actually fall slightly.

If the NSF is to enjoy an increase in funding, it looks like other civilian agencies of Government must suffer a commensurate cut. How about these priorities?

Dr. Keyworth. First of all, as I have said, we are focusing first and foremost upon talent, the use of that talent. The agencies, all of them, not just the National Science Foundation, that possess responsibilities for training and more basic research have seen increases—DOD, NASA, Office of Energy Research in DOE, et cetera. So, it has been broad.

But let me address military R&D for a second. I find it disturbing when I read more and more articles in news magazines, newspapers, et cetera, that castigate an emphasis upon high technology and defense. If we abandon high technology, then we are forced into playing on Soviet turf, so to speak. We need more emphasis, more utilization of the technology that comes from the world's greatest industrial base. In defense, we have been remiss in that area for a long time—all the way from training people that the Department of Defense will need to carry out its responsibilities in the future to development of new military systems. Now we are taking remedial action, and that is the reason for the 29-percent increase in the Department of Defense. But in turn, the highest priority in the civilian sector basic research has in no way suffered because of that increase in military R&D. Basic research is manpower intensive. Increases greater than those we have carefully thought about and submitted to the Congress, I think, cannot intelligently be accommodated, because the research is so terribly people intensive.

Senator Lautenberg. As a member of the Banking Committee, I have been involved in hearings and taken an interest in the p posal on the extension of the Export Administration Act. A la part of the debate there is whether or not there are too many restrictions. What is critical in terms of our defense needs to be made secret, classified, restricted material.

And there is a strong debate on that, obviously, going from one extreme in a part of the Defense Department to another extreme in a part of the Commerce Department, trying to serve the needs of our commercial base in the country.

Do you have an opinion on these proposals? Do you think we are too restrictive, too lenient? What I saw in executive session, and certainly I am not going to be revealing any military secrets here, because I did not understand what I was looking at, but the fact of the matter is that there are many discussions about basic civilian technology, fairly basic computers, IBM 360, going back to a fairly elementary computer system, as being classified.

I was shocked to find that out, because they are available in the market, yet it was restricted in terms of licenses. But much of the military development was based on very basic commercial development, the circuitry you buy in Radio Shack in little calculators and children's toys and things of that nature.

Do you think that there is a conflict there that ought to be treated any differently?

Dr. KEYWORTH. There is a very serious problem, and the fact that we have wrestled with this problem for many years testifies to its complexity. The problem, of course, is that the process is cumbersome. It is neither too restrictive nor too relaxed, but rather, it is too random.

There are very few Americans who would question that there are areas of technology that we need to restrict particularly from Soviet acquisition.

Let me just reference a common one. We absolutely must protect present U.S. leadership in the development of microprocessors. It is essential to maintaining our technological edge in defense technology. Well, how do we do this? By trying to restrict the key components, the key processing technologies. Clearly, there are some other things in sensitive arenas, such as Stealth technology, that we must very rigorously protect.

But when we place enormous emphasis on restricting the flow of a 20-year-old computer, I am afraid that it prevents the system from placing a proper emphasis on the areas that really do matter.

I think that is the problem. We have all heard about the Cocom problem and Cocom enforcement and the Cocom list, but basically we do not have an adequate mechanism for prioritizing what it is we wish to restrict.

Senator LAUTENBERG. The reason I mentioned that is because of your statement that so much of the development that takes place as a result of military emphasis is of value to the rest of the sector. I thought what we were hearing in those hearings was that the reverse was true.

Thank you very much, Dr. Keyworth.

Thank you, Mr. Chairman.

Senator HEFLIN. Let me ask you just one or two questions, and I may submit some questions in writing rather than taking up a lot of time.

On the issue of science and mathematics education nationwide, we all have heard a series of statistics that bothers us, the fact that 43 States have a shortage of qualified math teachers, 25 percent of the science and math teachers plan to leave the field soon, many for better paying jobs in industry, and two-thirds of all high schools require only 1 year of science and math, and that 69 percent of all science teachers have never had a course in computers, and so on, that type of thing.

Now, the administration has come out for a program designed to do it. I believe it is $75 million, which is to be a block grant.

First, do you feel that this is adequate to meet the needs, the proposal of the administration?

Dr. **Keyworth**. Senator, I think the problem is so large that there is no step we could take right now that is, let us say, adequate in the long term. I see the problem—both as an adviser to the President and as a parent of precollege children—as enormous, and it comes from a deemphasis upon education, not just science and mathematics. The problem with foreign languages is also serious. We spend, if I recollect, some $115 billion a year in the United States on precollege education. Yet we are trying to entice people into competitive areas, such as science and math teaching with salaries of $15,000 a year. We have a very large built-in problem, and the only way we are going to solve it is with broad public recognition and concern.

The Federal Government must take a strong leadership role and should exert levers where it can and where only it can. We are trying to do that. The block grant mechanism is by no means the only mechanism, and in my opinion is by no means the strongest mechanism. There are other programs, two others in the National Science Foundation, that directly address the quality, more than the number, of science and mathematics teachers in precollege institutions.

All of us are going to have to work together with industry, with teachers, and with the public in general to analyze the problem year after year—it continues to be an evolving problem—and find solutions. I worry about large block grants, because, as I said, the problem is not a hundreds of millions of dollars problem. It is a many tens of billions of dollars problem.

The Federal Government would be accepting a new responsibility that it cannot afford, in my opinion, if it were to attempt to solve the problem alone. It has got to work with others and address the problem year after year. This is a bipartisan issue; ideas and initiatives will evolve, but they must be thoughtful initiatives.

We have seen the danger of trying to solve the problems of the eighties with solutions of the sixties in some of the earlier National Science Foundation programs that lost their effectiveness. We have to be very thoughtful and very careful. But we have to be active.

Senator **Heflin**. The block grant approach toward this, as you mention, there are some other things, but in meeting the problems, we are going to have to develop new teaching techniques, new materials. There is going to have to be provided more scientific equipment.

Is the block grant approach a valid approach?

Dr. KEYWORTH. I will not categorically say that block grants are necessarily bad. Each State differs in its needs tremendously, and block grants do address that. There are some areas where modest block grants may be effective, but I think we must not delude ourselves into believing that, if you wish, putting money on the treestump is going to solve the problem by itself.

You addressed some of what I believe to be the key problems. How do we use new and emerging technology to improve our teaching methods? How do our curricula adapt to that? It will not be many years, I would project, before students at home will be able to do homework via telecommunications.

We have got to have vision in this, and the Federal Government has got to play a role. And I am afraid that perceiving block grants as an ultimate solution is a bit like trying to use dollar bills to plug a dike.

Senator HEFLIN. There is in this problem, and in the future, it seems to me, a need for ancillary emphasis on related subjects, and we cannot lose sight of, for example, the subject of English. As we go toward more computers, we are going to spit out more and more of the written word. The ability to communicate through clear and concise language is going to be more important.

I use that as an illustration for ancillary subjects to scientific emphasis and studies. It seems to me we cannot lose sight of those matters as we move forward.

I hope that the National Science Foundation will have programs that are designed to deal with this matter, the basic subjects that we are all dependent upon, particularly communications skills, and the application of communications skills in all sorts of computers and high technology, so we do not lose sight of those matters.

Dr. KEYWORTH. I think having tomorrow's youth taught by technicians rather than educated people is a threat. And I agree with you at the outset. You will notice I was a little hesitant to say that the problem was only in science in math. The problem is in education, peaking in science and mathematics. I think it is a problem we are going to be living with for probably a generation.

Senator GORTON. Thank you very much, Dr. Keyworth. We are delighted to have had you with us, and you have been most enlightening in your presentation today.

The balance of our witnesses, Dr. Knapp and Dr. Good, will speak now—Senator Lautenberg?

Senator LAUTENBERG. I was just going to say, before Dr. Keyworth left, that we had a semantic difference before which developed into a quantitative thing in terms of what percentage of the research at Bell Labs was basic research. I can use the same vernacular when describing our semantic difference in that we will agree, I think, a lot on science and educational policy. We may disagree sharply on social policy, as I hear the references to "block grant" and "welfare state" and things of that nature. But it will be pleasant to discuss those things as well another time. Thank you. That is what makes political parties.

Dr. KEYWORTH. That is what makes Government more interesting.

[The statement follows:]

STATEMENT OF DR. GEORGE A. KEYWORTH II, SCIENCE ADVISER TO THE PRESIDENT, AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Chairman Gorton and Members of the Committee, it's my pleasure to join you today to present a brief overview of the Administration's science policy and how it has guided the preparation of the President's array of proposed R&D programs for fiscal year 1984. I hope this perspective will prove useful in your consideration of the National Science Foundation programs being proposed for the coming year.

I don't think I'm exaggerating when I observe that federal science policy has gone through substantial changes in the past few years and that federal R&D programs reflect those changes in profound ways. As an immediate example, I don't think anyone would have predicted two years ago that you would be looking at the kinds of NSF programs being presented now. And similar observations can be made for other science agencies—such as the Office of Energy Research or NASA. Let me try to indicate how today's priorities came to be.

I believe one of the significant differences between this Administration and previous ones is that science and technology don't exist independent from the rest of government. They are thoroughly integrated into the planning analytical, and decision-making processes within the White House, and my own role is as an advisor who brings scientific and technical perspective or expertise to issues before the President. I am not there as an advocate for science but as someone who's determined that science and technology will be brought to bear on national problems and priorities. This focus on the health of the nation, rather than more narrowly on the health of science or technology, has resulted in this different alignment of R&D programs than we might have had in the past.

Please don't misunderstand. There's no question that we have to maintain and strengthen the health of our S&T enterprise as a national resource. But at the same time we have to make sure the nation gets the best possible return on its federal investments in science and technology.

As you look at our proposed programs for fiscal year 1984, you'll see evidence of the three general criteria that guided our deliberations. Let me describe them.

Mr. Chairman, in your invitation you asked me to comment on the Administration's vision of the future of basic research. I would say unequivocally that American science and technology today contain many fields of research that are clearly ripe for profound intellectual advances. The knowledge revolutions we've grown used to are continuing unabated, even accelerating, and our hard choices are those of choosing from among many, many, opportunities for federal support. So not surprisingly, much of OSTP's efforts require judgment in identifying and sorting out those opportunities. As you will notice, they constitute the areas of greatest emphasis in the R&D budget.

I would call special attention to the substantial emphasis we've placed this year on the basic research programs of the National Science Foundation. We're determined to capitalize on the remarkable opportunities that exist in such areas as physics, engineering, chemistry, plant biology, materials science, mathematics, astronomy, and many other areas of science. So that idea of intellectual opportunity is the first criterion we've used in putting together our federal programs in R&D.

Second: We recognize that R&D provides at least two tangible benefits to society. One is new knowledge that moves from the lab to society. We're determined to stimulate greater interaction of academic, federal, and industrial scientists and engineers, and to make sure the best R&D is supported well enough to permit rapid progress in developing new ideas that lead to technological innovation.

There's also a second benefit that is becoming increasingly important. As total federal and private R&D continues to increase, our nation's industrial and economic progress will become increasingly dependent on the availability of trained science and technical personnel. So we also have to look for ways to make sure that we derive educational and training advantages from federally supported research. One of the best ways to meet those needs is through university research in which students participate. Federal programs must make sure the academic research community is fairly treated in competition with other research performers.

The third criterion is the appropriateness of the role of the federal government in R&D. We've continued to shift the federal role away from demonstrations of technology and back towards its appropriate role of basic research and non-commercial development.

I said at the outset that R&D must serve the nation. How, then, are our major national goals affected by our R&D policy.

Defense is obviously a major element of the overall R&D budget. The United States relies heavily on maintaining a technological advantage over our adversaries—rather than trying to match up in terms of troop strength and deployment. Fiscal year 1984's growth in defense R&D is largely remedial, a necessary investment to restore the technological lead that was eroded during the 1970's.

The other primary concern is how federal investment and leadership in R&D can contribute to the nation's economic progress. We've tried to build into the proposed fiscal year 1984 programs ways to improve the interaction between fundamental research and its eventual applications in industry. We're also encouraging new kinds of interactions between universities, federal laboratories, and industry.

Throughout the budget, the common thread is our emphasis on basic research to fuel new technologies, and on the academic institutions that produce the trained personnel to drive our industrial growth. I want to point out quite clearly, though, that we're not proposing a general infusion of federal funds into R&D, even though many areas have experienced diminished support over the past decade. We don't propose new growth because it's good for science, and we don't intend to simply beef up a field by increasing the number of projects. The real return on this added investment will come from concentrating on the best projects we can identify and permitting those nuclei to grow into world-leading concentrations of research excellence.

Notwithstanding the tremendous federal investment in basic research over the past twenty years, we find many of the nation's academic institutions in poor shape—at least in the areas of physical sciences and engineering. This is partly because an inordinate share of that federal support has gone to non-academic institutions, particularly federal laboratories. With few exceptions universities have become less attractive places to pursue research careers in those fields. The quality of both research and education suffers from inadequate equipment and instrumentation. Because salaries for young faculty are too low to attract many top new PhD's into this deteriorating research environment, many forgo what, not many years ago, would have been their preferred career choices.

Somehow, in spite of all we've spent, we've arrived at the indefensible position of creating the poorest climate for research in the place that ought to have the best. That has to be changed, both to protect the world-leading basic research capability we've built up over three decades—and to make sure the universities can uphold the high standards for education that we've come to rely on from them.

Education is the critical problem underlying the future of our whole civilian and defense R&D capabilities. This single concern accounts to an important extent for our emphasis on Federal funding of research through the National Science Foundation and other university-oriented programs. For example, in fiscal year 1984 NSF basic research grants will support approximately 10,400 graduate students, who will then be available for the large S&T industrial personnel needs projected for the end of the decade and beyond.

There are other serious problems in education, as you well know, and throughout much of the past year we've also been consulting with professional groups and universities about them. The result is several specific new programs to address what we feel is the most critical problem: the inadequate supply of new junior engineering and science faculty in universities—and the shortage of qualified secondary school science and math teachers.

Presidential Young Investigator Awards, for example, will attract recent PhDs to university research who might otherwise choose non-teaching careers in industry. Other new programs are aimed at improving the supply of qualified science and math teachers in secondary schools. The costs for these education programs won't be great, but by concentrating resources strictly where they're most needed—on good faculty—we anticipate substantial long-term benefits.

We have every reason to expect this coming year to be a pivotal one for Federal R&D. The Administration has worked long and hard to structure a science and technology policy that address critical needs in our society—and to apply it. We're anxious to work with the Congress to set the country on a productive course to make the best possible use of the resources and potential of our universities, Federal laboratories, and industrial enterprise.

Mr. Chairman, the Office of Science and Technology Policy has been very actively involved throughout the year in formulating the Administration R&D programs I've described. We have, as well, conducted many activities that don't show up directly in the R&D budget, and I would be happy to discuss those with you. This concludes my formal presentation. I would be pleased to answer any questions from the Committee.

Senator GORTON. Dr. Knapp and Dr. Good. Dr. Knapp, please proceed.

STATEMENTS OF DR. EDWARD KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION, AND DR. MARY L. GOOD, VICE PRESIDENT AND DIRECTOR OF RESEARCH, UOP, INC.

Dr. KNAPP. Thank you.

We are very pleased to be here this morning. I will summarize very briefly my statement, and submit the full statement for the record.

Senator GORTON. Please do. Your entire statement will be included in the record.

Dr. KNAPP. Mr. Chairman and members of the committee, this is my first appearance before your committee. I am very pleased to be here and to be accompanied by Dr. Mary Good, Vice Chairman of the National Science Board and vice president and director of research for UOP, Inc.

When I have completed my overview of the Foundation and its planned program for 1984, Dr. Good will describe the role of the National Science Board in developing our program priorities for 1984, as well as other recent activities of the Board.

The Foundation occupies a unique place in the research community and among Federal agencies that sponsor research. The staff of the Foundation does not conduct research, though its program officers are virtually all scientists or engineers with research experience in the fields for which they are responsible.

Our funds, in the form of grants and contracts, support scientists and engineers outside the Government, most frequently in universities and colleges. The creative ideas on which research is conducted come from the scientists and engineers themselves in the form of unsolicited research proposals. Each year, the Foundation receives over 27,000 proposals. With the assistance of close to 50,000 scientists, engineers, and educators serving as advisers and peer reviewers, we select and support about 10,000 of these proposals.

NSF awards provide support for the tools and research facilities that permit scientific advancement in many disciplines. This support ranges from purchases of equipment in individual research projects to the support of major user facilities in physics and materials research, the academic research fleet in oceanographic research, five national astronomy centers, and a national atmospheric research center, and in addition, the Foundation funds and manages the U.S. Antarctic program, the principal expression of active U.S. interest in that continent under the Antarctic Treaty.

Those who serve as peer reviewers and advisers donate their time to the Foundation, because they believe it is important work. This is the key to our ability to conduct business with an overhead of less than 6 percent of our total funding.

The Foundation's programs are especially important for our colleges and universities. These are the institutions in which most long-term fundamental research is carried out, and in which our graduate scientists and engineers are trained through a research apprenticeship system which I believe has no equal anywhere in the world.

In some sense, almost the entire Foundation budget goes for science and engineering education. In recent years, more than 25 percent of the Federal support for basic research at universities and colleges has been provided by NSF. In some fields of science, such as mathematics, ground-based astronomy, anthropology, and geology, as much as 90 percent of basic academic research is supported by the Foundation.

The Foundation has supported and continues to support some small but critically innovative research programs which provide a bridge between R&D, and industry, and academic basic research. The Foundation encourages industry-university cooperation in fundamental research using different modes.

The industrial-university cooperative research projects and another program called the Industry-University Cooperative Research Centers, the former focuses on research carried on by scientists collaborating as individuals with university and industry partners sharing their expertise and viewpoints. The latter program stimulates university-industry interaction by providing the initial support for on-campus research centers in areas of generic technology.

NSF's small business innovation research program, initiated in 1977, served as the prototype for that program, enacted by the Congress in the Small Business Innovation Development Act of 1982. As in other Foundation programs, funds are awarded on a peer reviewed, competitive basis. The first phase is a study of the feasibility of an idea. After further review, the most promising projects are provided second-phase funding. The final development into commercial form is carried out solely with private venture capital.

Let me now turn to a summary overview of the program which we are planning for 1984. Our budget request totals $1.292 billion, a 17.8-percent increase over fiscal year 1983. We are proposing a strong, well-balanced program through which we will support and continue a great deal of very exciting basic research, with particular emphasis on areas of great potential promise to our future economic well-being and technological capabilities.

I would like to emphasize three things about our program. First, support for the conduct of basic research is increased by 18.3 percent over 1983. This rate of growth in a period of general economic and budgetary stringency reflects the importance which the President attributes to basic research for laying the groundwork for a sustained economic recovery, and recognition of the need to revitalize the research base in the Nation's universities and colleges.

This will enable NSF to step up significantly its support of high quality research.

Second, our plans for 1984 contain three programs which the President has selected for special emphasis. Two of them, planned for initiation in 1983 and proposed for expansion in 1984, are designed to improve the quality of teaching in science and mathematics in the Nation's secondary schools.

We are waiting for final congressional approval of these two initiatives.

The third, to be started in 1984, is designed as a cooperative Government-private-sector program to support the brightest young scientific and engineering faculty in order to encourage them to continue their academic and teaching careers.

Third, our 1984 program will effect a new management philosophy for the Foundation's special set-aside programs for such things as international activities, women and minorities, and undergraduate educational institutions. Beginning in 1984, our research program officers will be required to adopt a much broader view of their responsibilities toward the health of science.

These certified programs will be integrated budgetarily and managerially into the mainstream of the Foundation's research activities. The integration of these activities into the main line research programs of NSF in 1984, I believe, will enhance greatly and more permanently our support of women, minority, undergraduate, faculty, research, and international activities in the Foundation.

It will also further our goal of broadening the attention of the Foundation to the overall health of science and technology in the United States.

In formulating our program for 1984, several important criteria were used. These include the scientific excellence and promise of the activity, the need to sustain scientific momentum in certain key areas, maintain a broad base of support across a wide variety of science and engineering disciplines, and the potential for an activity to contribute to important national economic and productivity goals.

Let me now mention some additional highlights of our 1984 program. Overall emphasis is given to the physical sciences and engineering, with special attention to mathematics, materials research, astronomy, Earth science, mechanical, electrical, and computer engineering. Within the biological sciences, priority is given to research on plant biology.

Support for the social and economic sciences is substantially increased above 1983, especially in those areas, economics and decision management science, with significant potential for contributing to our long-term economic goals.

In 1984, most of the Foundation's programs place a very high priority on instrumentation, with support estimated to increase by 61 percent over 1983. Support of crustal research on the ocean floor and continents will increase by one-third, to a total of almost $68 million. This will provide for continuation of scientific ocean drilling.

A new program is planned aimed at the Nation's undergraduate colleges and designed to encourage and strengthen independent faculty research and the use of advanced undergraduates as research assistants.

Support of international scientific activities, including a new United States-India cooperative science program, will be increased and more closely integrated into the Foundation's major research programs. Increased support is provided for research involving cooperation between university and industrial scientists and engineers.

In conclusion, Mr. Chairman, the increase requested for the Foundation's 1984 programs reflects the importance the administration has assigned to basic research for laying the groundwork for long-term stable economic recovery and growth, and for national security. With this goes the recognition that we need to begin modernizing the research and instrumentation base of our colleges and universities and improving the quality of science and mathematics training in our schools so that the Nation may obtain outstanding scientists and engineers and well-prepared technicians to maintain and improve U.S. leadership in science and technology.

It is my pleasure to submit for your approval today a balanced program that I believe will help create new knowledge and highly trained scientists and engineers who contribute significantly to scientific and technological benefits for the Nation and its citizens.

I would like Dr. Good to give her testimony now.

[The statement follows:]

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and Members of the Committee, this is my first appearance before your Committee and I am very pleased to be here and to be accompanied by Dr. Mary L. Good, Vice Chairman of the National Science Board and Vice President and Director of Research, UOP Inc. When I have completed my overview of the Foundation and its planned program for fiscal year 1984, Dr. Good will describe the role of the National Science Board in developing our program priorities for fiscal year 1984 as well as other recent activities of the Board.

The Foundation occupies a unique place in the research community and among Federal agencies that sponsor research. Let me explain, briefly, why I believe this to be so. First, the staff of the Foundation does not conduct research, though its program officers are virtually all scientists or engineers with doctoral degrees and research experience in the fields for which they are responsible. Our funds, in the form of grants and contracts, support scientists and engineers outside the government, most frequently in universities and colleges.

Second, the creative ideas on which research is conducted come from the scientists and engineers themselves in the form of unsolicited research proposals. Each year, the Foundation receives over 27,000 proposals. With the assistance of close to 50,000 scientists, engineers, and educators serving as advisors and peer reviewers, we select and support about 10,00 of these proposals.

NSF awards provide support for the tools and research facilities that permit scientific advancement in many disciplines. This support ranges from purchases of equipment in individual research projects to the support of major user facilities in physics and materials research, the academic research fleet in oceanographic research, five national astronomy centers, and a national atmospheric research center. In addition, the Foundation funds and manages the U.S. Antarctic Program, the principal expression of active U.S. interest in that continent under the Antarctic Treaty.

Those who serve as peer reviewers and advisors donate their time to the Foundation because they believe it is important work. This is a key to our ability to conduct business with an overhead of less than 6 percent of our total funding. I believe that the competitive nature of the Foundation's award process is the cornerstone of our ability to support the most promising work from researchers across the Nation.

Third, the Foundation's programs are especially important for our colleges and universities. These are the institutions in which most long-term, fundamental research is carried out and in which our graduate scientists and engineers are trained through a research apprenticeship system. This apprenticeship system is the main reason NSF awards go primarily to academic researchers. Thus, in some sense, almost the entire Foundation budget goes for science and engineering education.

In recent years, more than 25 percent of the Federal support for basic research at universities and colleges has been provided by NSF. In some fields of science, such as mathematics, ground-based astronomy, anthropology, and geology, as much as 90 percent of basic academic research is supported by the Foundation. One-third of the fundamental work in universities and colleges in engineering is provided by NSF. The linkup between research and education in universities means that NSF research funds are a vital component in the training of the future scientists and engineers who will staff our industrial, governmental, and academic laboratories.

Fourth, the Foundation has supported and continues to support some small but critically innovative research programs which provide a bridge between R&D in industry and academic basic research. While industrial funds make up only about 4 percent of separately budgeted R&D expenditures at academic institutions—and in disciplines such as engineering the amount goes as high as 10 percent—it has been the fastest growing source of support for academic R&D since 1967.

Real growth in industrial support for academic research averaged 10.4 percent per year between 1977 and 1980. Federal growth averaged only 6 percent. The recent spate of multi-year agreements in biotechnology announced in mid-1981 are not reflected in these industry figures. Though industry's investments in R&D spending at universities and colleges are less than 1 percent of its overall R&D spending, it is as much as 30 percent of the industrial long-range research effort.

The Foundation encourages industry/university cooperation in fundamental research using different modes: Industry/University Cooperative Research Projects and Industry/University Cooperative Research Centers. The former focuses on research carried out by scientists collaborating as individuals with university and industry partners sharing their expertise and viewpoints. The latter program stimulates university/industry interaction by providing the initial support for on-campus research centers in areas of generic technology, e.g., polymer processing at MIT, computer-aided design at Rensselaer Polytechnic Institute, robotics at the University of Rhode Island, and welding at Ohio State. At present, MIT's center has become self-supporting, after the initial Foundation support; the RPI, Rhode Island, and Ohio State centers now receive between 60 and 90 percent of their funding from industry.

NSF's Small Business Innovation Research Program, initiated in fiscal year 1977, served as the prototype for that program enacted by the Congress in the Small Business Innovation Development Act of fiscal year 1982. As in other foundation programs, funds are awarded on a peer reviewed, competitive basis; a first phase for the study of the feasibility of an idea. After further review, the most promising projects are provided second phase funding. The final development into commercial form is carried out solely with private venture capital.

FISCAL YEAR 1984 PROGRAM

Let me now turn to a summary overview of the program which we are planning in fiscal year 1984. Our budget request totals $1,293.3 million, a 17.8 percent increase over fiscal year 1983. We are proposing a strong, well balanced program, through which we will support and continue a great deal of very exciting basic research with particular emphasis on areas of greatest potential promise to our future economic well-being and technology capabilities. It will also help restore and maintain quality education in science and mathematics in our Nation's secondary schools and strengthen research training for graduate science and engineering students in our colleges and universities. I am confident that it will move this country toward the President's goal of maintaining the technological leadership of the United States.

I would like to emphasize three things about our program. First, support for the conduct of basic research is increased by 18.3 percent over fiscal year 1983. This rate of growth in a period of general economic and budgetary stringency reflects the importance which the President attributes to basic research for laying the groundwork for sustained economic recovery and recognition of the need to revitalize the research base in the Nation's universities and colleges. As Dr. Keyworth recently observed:

"Over the past twenty years, our academic institutions have grown shabby. With few exceptions they have become less and less attractive places to pursue research. Equipment and instrumentation are not as good as that in national labs, or in many industries. Somehow, we have arrived at the indefensible position of creating the poorest climate for research in the place that ought to have the best."

An increase of 18.3 percent for the conduct of basic research will enable NSF to step up significantly its support of high quality research. The funds will provide greater support for our most gifted researchers and graduate students and for research instrumentation to enable them to accelerate their pursuit of challenging research opportunities.

Second, our plans for fiscal year 1984 contain three programs which the President has selected for special emphasis. Two of them, planned for initiation in fiscal year 1983 and proposed for expansion in fiscal year 1984, are designed to improve the quality of teaching in science and mathematics in the Nation's secondary schools. We are waiting for final Congressional approval of these two initiatives. The third, to be started in fiscal year 1984, is designed as a cooperative government/private sector program to support the brightest young scientific and engineering faculty in order to encourage them to continue their academic and teaching careers.

Third, our fiscal year 1984 program will reflect a new management philosophy for the Foundation's special "set aside" programs for such things as international activities, women and minorities, and undergraduate educational institutions. Beginning in fiscal year 1984, our research program officers will be required to adopt a much broader view of their responsibilities toward the health of science. These "set aside" programs will be integrated, budgetarily and managerially, into the mainstream of the Foundation's research activities. Over the years, there have been problems with these programs. These problems include the perception, external to NSF, that quality control is not as good as it is in the mainline research programs. There is also the feeling within the Foundation that one purpose of such programs, namely to familiarize targeted groups with mainline research funding procedures, has not worked effectively, because these targeted groups are not introduced to, nor do they work with, the relevant research program managers. Thus, separate management has made working these targeted groups and institutions into the mainstream of research more, not less, difficult. And, finally, the very existence of special programs conveys an impression in the mind of program officers that these targeted issues are somehow beyond their purview in grant award decisions, despite their clear bearing on the overall health of science and engineering.

The integration of these activities into the mainline research programs of NSF in fiscal year 1984, I believe will enhance—greatly and more permanently—our support of women, minority, undergraduate faculty research, and international activities in the Foundation. It will also further our goal of broadening the attention of the Foundation to the overall health of science and technology in the U.S.

FISCAL YEAR 1984 PROGRAM HIGHLIGHTS

In formulating our program for fiscal year 1984, several important criteria were used. These included: the scientific excellence and promise of the activity; the need to sustain scientific momentum in certain key areas; maintenance of a broad base of support across a wide variety of science and engineering disciplines; and the potential for an activity to contribute to important national economic and productivity goals.

Let me now mention some additional highlights of our fiscal year 1984 program:

Overall emphasis is given to the physical sciences and engineering, with special attention to mathematics; materials research; astronomy; earth science; and mechanical, electrical and computer engineering.

Within the biological sciences, priority is given to research on plant biology. Work in this scientifically exciting and economically important area will include such topics as nitrogen fixation and the mechanisms for synthesis of carbohydrates.

Support for the social and economic sciences is substantially increased above fiscal year 1983, especially in those areas—economics and decision and management science—with significant potential for contributing to our long-term national economic goals.

Sophisticated instrumentation, measuring devices and data processing equipment are of central importance to the conduct of cutting-edge research in virtually every field of science and engineering today. In fiscal year 1984 most of the Foundation's programs place a very high priority on instrumentation, with support estimated to increase by 61 percent over 1983.

Support of crustal research on the earth's ocean floor and continents will increase by one-third to a total of almost $68 million. This will provide for continuation of scientific ocean drilling.

A new program is planned aimed at the Nation's undergraduate colleges and designed to encourage and strengthen independent faculty research and the use of advanced undergraduates as research assistants.

Support of international scientific activities, including a new U.S./India cooperative science program, will be increased and more closely integrated into the Foundation's major research programs.

In the U.S. Antarctic Program, two major capital investment projects are proposed—replacement of a large maintenance facility destroyed by fire in 1981 and beginning a Service Life Extension Program for the two oldest LC–130 ski-equipped Hercules aircraft.

Increased support is provided for research involving cooperation between university and industrial scientists and engineers, and the Small Business Innovation Research Program will be sustained at the level required by the Small Business Innovation Research Act passed last year.

CONCLUDING REMARKS

In conclusion, Mr. Chairman, the increase requested for the Foundation's fiscal year 1984 programs reflects the importance the Administration has assigned to basic research for laying the groundwork for long-term, stable economic recovery and growth and for national security. With this goes the recognition that we need to begin modernizing the research and instrumentation base of our colleges and universities and improving the quality of science and mathematics training in our schools so that the Nation may obtain outstanding scientists and engineers and well-prepared technicians to maintain and improve the United States' leadership in science and technology.

It is my pleasure to submit for your approval today a balanced program that I believe will help create new knowledge and highly trained scientists and engineers who contribute significantly to scientific and technological benefits for the Nation and its citizens.

[The following information was subsequently received for the record:]

Questions of the Committee and the Answers Thereto

Question. Will the number of research grants change with the increase in the NSF budget? What is the rationale for this policy and what implications will it have on young scientists just entering the grants competition?

Answer. The number of awards anticipated for fiscal year 1984 is expected to be slightly greater than that estimated for fiscal year 1983; 13,348 as compared to 13,203. In the fiscal year 1984 Budget Request, the Foundation has given priority to providing the best investigators with the resources needed to maintain excellence in their research. For example, additional support would go toward acquisition of critically needed instrumentation, for accelerating research in areas of particular scientific promise, or providing increased support for young faculty investigators and graduate students. Because of major differences between various scientific disciplines, the particular emphasis will vary across the Foundation's activities and subactivities. Where particular attention required, several areas—such as plant biology and the mathematical sciences—plan to support post doctoral fellowships to help improve the flow of young scientists into research careers. The fiscal year 1984 Budget Request also includes $6.0 million for Presidential Young Investigator Awards to support research efforts of outstanding young faculty members for up to five years in scientific and engineering fields where demonstrated needs exist. Moreover, NSF expects that the success ratio for young scientists—which past experience has indicated is comparable to that for senior investigators—will not change significantly.

Question. In your statement you referred to the new management philosophy that will integrate previously "group-specific" research and educational programs into the mainstream of NSF research activities. Would you elaborate on how you intend to do this?

Answer. In the future, the research directorates will be expected to assume broader responsibilities for the health of science and engineering. I am proposing that program officers, in planning and budgeting for their disciplines, specifically consider many areas which have for the last several years been planned and managed separately. These areas include support of undergraduate student and faculty research, minorities and women, and international science activities. Responsibilities for proposal generation, evaluation, and decisionmaking would shift to the research directorates. STIA program officers would provide agency-wide coordination and other support for these activities.

Certain of these areas, and particularly international science, will require agency-wide coordination. This will be the responsibility of the STIA directorate. In addition, I intend to establish an internal tracking system to ensure that resources devoted to these areas are maintained at least at their current levels.

A detailed implementation plan is currently being developed by a steering group composed of the Assistant Directors for Biological, Behavioral and Social Sciences; Astronomical, Atmospheric, Earth and Ocean Sciences; Mathematical and Physical Sciences; Engineering; Scientific, Technological and International Affairs; Administration; and the Director of the Office of Scientific and Engineering Personnel and Education. This plan will: (1) define responsibilities of the coordinators and the research program managers; (2) design a tracking system; (3) consider advice from the National Science Board, Committee on Equal Opportunities in Science and Technology, Office of Management and Budget, Office of Science and Technology Policy, and other groups; and (4) recommend any personnel adjustments that might be required for the new arrangements to work optimally.

Question. If the research activities of the Foundation support about 90 percent of the graduate and post-doctoral students NSF supports, why are the NSF Graduate Fellowships funded in a special science education component?

Answer. The research activities of the Foundation provide for about 90 percent of the graduate and post-doctoral students that NSF supports as part of the research award. Funds are provided for post-doctoral, graduate, or undergraduate research assistants to assist in the conduct of the research. The appointment of these research assistants is the responsibility of the principal investigator and may include foreign nationals.

In contrast, NSF Graduate Fellowships are awarded on an individual basis highly talented United States citizens identified in a national competition, who are beginning graduate study. Awards are portable and made on the basis of merit in all fields of science and engineering and may be used at an institution of the awardee's choice. The awards are not tied to a particular research grant or principal investigator. The full-time study support provided these graduate students fellows, in the past, has accelerated the fellows' progress toward active and distinguished science and engineering careers.

NSF Graduate Fellowships provide tangible Federal recognition to highly talented graduate students studying science and engineering. Because they cover all disciplines and are independent of specific research projects, they require a special review system. For this reason, the Graduate Fellowships have been administered as a separate program distinct from the research activities. In the Foundation's view, this arrangement has proved effective and efficient and should remain unchanged.

Question. Last year the Directorate for Science and Engineering Education was disestablished and the NSF science education activities were placed in the Office of the Director. Under what circumstances would you consider the Directorate's re-establishment?

Answer. The Directorate was disestablished as a result of the large reduction in the scope and functions of the science education activities of the Foundation. Any changes in organizational status and structure will be based on changes in scope and funding levels that may occur in the future.

Question. You mentioned earlier about broadening program officers' responsibilities and you emphasized the relationship between research and education. Can precollege activities—whether they be focused on teachers, students, or the broader public—be effectively managed and integrated with research activities, or is the precollege component a legitimate focus for perhaps a newly re-established directorate should additional resources become available?

Answer. Precollege activities will continue to require separate management, either through the current Office of Scientific and Engineering Personnel and Education or some other appropriate organizational entity. Advice and cooperation in planning future NSF activities in this area will be sought from the research directorates.

Question. In your testimony you emphasized the "central importance" of instrumentation. With the well-documented evidence of the need or improved research instrumentation, this appears to be a prudent use of scarce resources. However, it is imperative that these initiatives be managed in a way that makes meaningful progress in this area. How do you propose to move ahead in the modernization of research instrumentation?

Answer. Obsolescence of university research instrumentation is pervasive and undermines the Nation's capacity to perform science of the highest possible quality and limits the effectiveness of graduate training. Scientific research is not monolithic; various scientific and engineering disciplines have different styles and varying equipment needs. Consequently, meaningful modernization of university research instrumentation can best occur within the context of each discipline.

Each of the Foundation's programs will address support of research instrumentation in ways most appropriate to it. This strategy permits maximum flexibility as to size, cost, and methods of attending to the equipment needs in each disclipine. Some disciplines will meet these needs by including support in regular research projects. Other disciplines use special equipment programs to help address such needs, and some focus on major facilities.

NSF proposes to move ahead on this problem by providing increased resources in a strategy that allows the research activity to select the mix of instrumentation funding mechanisms most appropriate to its area of research.

Question. Can you elaborate on the new relationship between STIA and the research directorates? What is the rationale for the change? How will this new relationship affect the program staff? What new responsibilities will they have? How do you feel it will affect attention to programs for women and minority scientists as well as programs in international science?

Answer. Under the proposed distribution of management responsibility, STIA program officers and research directorate program officers would work in a partnership style. Some programs, e.g., international, women and minorities, etc. would be jointly planned and managed. This revised relationship is being proposed because, in the past, the separation of "special" programs has led to the perception that they are somehow tangential to the Foundation's mission and perhaps of lesser quality. This earlier system has not served the NSF goals of advancing and maintaining the health of U.S. science as well as is possible.

Program officers in the research directorates will be expected to assume broader responsibility for the whole range of issues of their scientific disciplines. STIA program officers would provide coordination across Directorates and monitor overall agency achievements in these programmatic areas. While the exact distribution of management responsibility is not yet determined, it is expected to vary from program to program. Different arrangements are presently being studied by a steering group of Assistant Directors. The arrangements chosen for individual programs will build on the strengths of both STIA and the research directorates in each case.

By distributing responsibility for concern for and sensitivity to issues such as the full utilization of minority and women scientists throughout the Foundation, we expect that opportunities for support will actually be increased. By interacting with research directorate program officers from their initial contacts with NSF, these groups will be in closer contact with the research program officers and the research communities they represent. The current separateness should be eliminated, thus giving access to a much more substantial research support base.

In the international area, one of the important potential outcomes of distributing responsibility between STIA and the research directorates is that programs will be jointly designed. This collaborative planning and management should enhance the quality of proposals and increase the participation of U.S. scientists in research efforts designed under bilateral agreements. The STIA staff would have responsibility for maintaining up-to-date awareness of international science and engineering issues and opportunities, international protocols, applicable laws and broad U.S. government policies and priorities, and for keeping the senior management staff and the research program officers fully informed of these matters. The research directorate program officers would handle all proposal processing and evaluation. They would continue to work closely with STIA staff, but all final funding decisions would rest with the research directorates. This system should, over time, lead to expanded international scientific cooperation, which could enhance U.S. science and engineering.

Question. Almost half of the proposed increased for Computer Research is proposed for a Coordinated Experimental Research Program. What types of research activities would these funds support?

Answer. The objective of the Coordinated Experimental Research Program is to improve the experimental research facilities of a relatively small number of universities that have strong research faculties. This Program, initiated in fiscal year 1980, was designed to redress the poor condition of computer research laboratories at most universities, and to stimulate experimental computer research. The Coordinated Experimental Research Program funds the purchase of hardware and software, supports technical and professional support personnel, and provides funds for necessary maintenance and operating costs of research facilities. It does not directly fund research projects, rather it provides the experimental research facilities and instrumentation essential to the conduct of experimental research.

The facilities provided opportunities for research in a variety of areas including networking and distributed processing, circuit design, computer architecture, database management, operating systems, program verification, performance evaluation, natural language processing, computer graphics, parallel processing, and image processing. The development of CSNET, the Computer Science Research Network, also continues to be a major activity of this program.

Question. Would you comment on the state of U.S. computer science versus the work the Japanese are undertaking?

Answer. U.S. computer research and development activities range in character from the generation of new ideas and understanding, to product development. To date, Japanese computer R&D has emphasized applied research and product development. A large part of Japan's success has been achieved by selecting technological opportunities and coordinating applied research among the major Japanese computer companies.

Academic research in the U.S. emphasizes fundamental research, a component which has been largely missing in Japan in the past. For the first time, two Japanese projects on supercomputers are being pursued which include basic research components. The basic and applied research portions are to be coordinated among the participating companies, universities, and a worldwide network of consultants. Product development is to be left to the individual companies. Because of anti-trust considerations, in the U.S., such coordination occurs only within a single very large company such as IBM or, in special cases such as the Very High Speed Integrated Circuits (VHSIC) program in the Department of Defense projects. In 1982, two new U.S. consortia of computer companies (The Semiconductor Research Consortium and the Microelectronics Computer Consortium) were formed to provide industry-wide coordination for participating companies.

Top quality researchers are available in both countries. Comparison of the R&D support in the two countries is complicated not only by fluctuating exchanges rates but also by the fact that in addition to government budget monies, corporate budgets and entrepreneurial funding are involved. A reasonable measure of the relative R&D effort by the U.S. and Japan is the number of patents granted in the computer and microelectronics area. The ratio of the number of patents by U.S. firms to the number of patents by Japanese firms has been two-to-one in the very recent past.

Question. Relative to other programs in mathematics and physical sciences, computer research received a smaller increase. Could you explain the rationale for this?

Answer. During the past several years computer research has been a subactivity of high priority within the Mathematical and Physical Sciences, and it remains so in the fiscal year 1984 Budget Request. Computer research received preferential funding increases relative to the other MPS disciplines in fiscal years 1981, 1982, and 1983. These increases were used to implement a long range plan designed to strengthen the capability of academic institutions to conduct modern experimental research through the establishment of first-rate computer research facilities. Implementation of this plan continues in the fiscal year 1984 Budget Request, which provides for the initiation of 4–5 additional computer research facilities, as well as the strengthening of individual research projects in the discipline. The percentage increases requested for the other MPS disciplines reflect priorities and needs in addition to those in computer research, particularly in the mathematical sciences and in materials research.

Question. Federal support for oceanographic research has declined substantially since 1976. Thus the importance of NSF's role has greatly increased. In light of this, would you explain why the ocean sciences received the smallest percentage increase within the Astronomical, Atmospheric, Earth and Ocean Sciences (AAEO) Directorate?

Answer. The percentage increase in the Ocean Sciences Subactivity from fiscal year 1983 to fiscal year 1984 was 9.76 percent which was smaller than the corresponding increases for other divisions within AAEO. However the increase for Ocean Drilling Program from fiscal year 1983 to fiscal year 1984 was 59.4 percent. This increase is required to operate a drilling program in fiscal year 1984 in the absence of foreign partners. Since scientific ocean drilling is an integral part of oceanographic research, the combined increase for the Ocean Sciences and Ocean Drilling Programs from fiscal year 1983 to fiscal year 1984 was 18.1 percent, which is comparable to the increases that the other AAEO supported disciplines received.

Coordination is conducted with National Oceanic and Atmospheric Administration (NOAA) primarily through:

The Federal Oceanographic Fleet Coordinating Council (FOFCC) that meets 2 or 3 times a year to resolve problems common to the Federal fleets. The Council is made up of the representatives of agencies that operate research ships: NSF, NOAA, U.S. Coast Guard, U.S. Geological Survey, Naval Research Laboratories, and the Environmental Protection Agency.

The FOFCC Ship Coordination Board that meets frequently to resolve ship coordination problems.

The University-National Oceanographic Laboratory System (UNOLS), an organization made up of representatives of research ship operating institutions. The UNOLS East and West scheduling committees are charged with establishing ship schedules integrating all agencies-supported research among the 25-ship UNOLS fleet. The scheduling includes the majority of all NSF-supported field research as well as some of NOAA's.

A Memorandum of Agreement between NOAA and NSF that enhances coordination mechanisms between the two agencies in marine science.

Question. Your Crustal Studies Task Force recently issued its recommendations. What are these recommendations and would you discuss their implications for the ocean drilling program at NSF?

Answer. The Ad Hoc Advisory Group on Crustal Studies met at NSF on February 3 and 4 to discuss priorities in this area of research.

The Charge to the Ad Hoc Advisory Group was to:

Review long range plans for crustal studies within the university-based earth and ocean sciences;

Assign relative priorities to initiatives in crustal studies in the context of likely budgets for fiscal year 1984 and future years with particular attention to the relative priority to be assigned to ocean drilling;

Within the framework of these priorities, advise on the relative merits of Challenger, Explorer, or a third platform;

Consider what mix of research programs and associated facilities, within constrained budgets, best addresses the scientific opportunities in crustal research; and

Prepare a report on these issues.

The Group discussed plans for crustal studies with the Directors of the Earth and Ocean Sciences Divisions and the Head of the Office of Scientific Ocean Drilling. In the case of ocean drilling, the relative costs and capabilities of Challenger, Explorer and a representative modern commercial drill ship were analyzed in detail.

The Group unanimously recommended that a program of ocean drilling be continued. They recommended against further efforts to develop Explorer as a drill ship, and considered the use of Challenger for a few more years to be feasible but not favored option. Instead, they recommended that NSF seek to lease a modern commercial drill ship and advised that, because of the depressed state of the oil market, favorable terms should be attainable.

Question. Over half of the total increase for the BBS Directorate is for Physiology, Cellular, and Molecular Biology. Within this area, as well as in the Biotic Systems and Resources, you tend to emphasize the plant sciences. Why do you believe that the plant sciences are ripe for this emphasis?

Answer. There are several reasons for assigning high priority to research in the plant sciences. Most important are the scientific opportunities and the likely contributions to scientific knowledge made possible by such newly developed techniques in plant research as recombinant DNA. These developments make possible research on the molecular biology and genetics of plants that was heretofore not feasible. Essentially, a whole new research area is being opened for study. Secondly, modern research in the plant sciences has been relatively neglected compared to research on animals and microorgansims, this despite the importance of the area. Third, research on the molecular aspects of plant-animal interactions provides a strong scientific basis for improving plant management practices; e.g., integrated pest management. Scientific advances in biotechnology, integrated pest management, and exploration of genetic diversity in crop-plant species hold promise of alleviating shortages of the food and fiber required to support an increasing world population. In summary, it appears that the scientific tools needed to make major advances in this important field are available and waiting to be exploited. Major scientific and societal benefits are likely.

Question. Also within the BBS directorate, in the social and economic sciences, economics received more than half the total increase. Could you explain the rationale for this and what the ramifications will be for the other social sciences?

Answer. The planned higher rate of growth for economics reflects the fact that many of the critical issues confronting modern societies—unemployment, productivity, economic growth and development—have a preponderant economic component. Earlier NSF investments in such research have helped to build a strong theoretical and methodological basis, and sound infrastructure, for investigating these types of problems. To facilitate carrying out such fundamental research, funding responsibility for the Panel Study of Income Dynamics has been transferred to Economics from another program in the Division. This shift accounts for about half the requested increase in the Economics program.

Question. You have proposed a 24.1 percent increase in the operations component for the U.S. Antarctic Program. Have you investigated the possibility of transferring some of these support costs to other agencies, such as Defense or Transportation which also have ongoing programs in the Antarctic?

Answer. The Department of Defense and Transportation do not have ongoing programs in the Antarctic. Their activities there consists of providing, on a reimbursable basis, the logistics support requested by the National Science Foundation, the single agency charged with funding and management of the U.S. national program in Antarctica.

The possibility of transferring some or all of the support costs to other agencies has been examined on several occasions since this responsibility was assigned to NSF.

Based on an in-depth Antarctic Policy Group (APG) study, the National Security Council (NSC) recommended to the President in May 1970 that the budget responsibility for the program be transferred to NSF. The President approved the recommendations which were announced in National Security Decision Memorandum 71 of July 1970. The funding transfer became effective for fiscal year 1972. The Department of Defense (DOD) and the Department of Transportation (DOT) were directed to maintain the capability to support the program. (The APG membership consists of the Department of State (chair), Department of Defense, and the National Science Foundation).

In fiscal year 1976 another Presidential decision reaffirmed the previous policy that NSF would "budget for and manage the entire U.S. national program in Antarctica" and specified that NSF would "draw upon logistic support capabilities of Government agencies on a cost-reimbursable basis."

Effective for fiscal year 1977, in accordance with Administration policy, the NSF budget included funds to reimburse the U.S. Coast Guard for the incremental cost of providing icebreaker services in support of the Antarctic Program. Effective for fiscal year 1983, the Administration distributed the fixed costs of maintaining the polar icebreaker fleet to the user agencies. NSF's proportionate share was $13,400,000 and funds were transferred from the U.S. Coast Guard budget base to the NSF budget for fiscal year 1983 to allow NSF to reimburse the U.S. Guard.

In a study completed in 1978, the General Accounting Office concluded there should be no change in the basic roles of the various agencies involved in the program. This study was undertaken at the request of the Senate Foreign Relations Committee.

During 1979, the Science Research and Technology Subcommittee of the House Science and Technology Committee conducted oversight hearings on the Antarctic Program with particular reference to the role of DOD in support of the Program. No changes in funding arrangements were recommended as a result of the hearings.

In a memorandum dated February 5, 1982, President Reagan reaffirmed the two earlier Presidential decisions that NSF should continue to "budget for and manage the entire United States national program in Antarctica, including logistic support activities so that the program may be managed as a single package." This decision, as was the case in the two previous decisions, was based on detailed study on U.S. objectives in Antarctica by the Antarctic Policy Group.

Question. What is the relationship of NSF to the Department of State with regard to the U.S. Antarctic Program?

Answer. The Department of State is responsible for the formulation of foreign policy and the provision of foreign policy direction relating to the development and implementation of an integrated U.S. program for Antarctica, for the conduct of foreign relations regarding Antarctica, and for legal matters relating to the interpretation and implementation of the Antarctic Treaty.

The Antarctic Policy Group, chaired by the Department of State, with membership from the Department of Defense and the National Science foundation, is responsible for providing policy guidance to the National Science foundation regarding program content.

Representatives of U.S. Federal agencies, under guidance of the Department of State, conduct periodic inspections, as provided for under Article VII of the Antarctic Treaty, of non-U.S. Antarctic installations. The inspection teams are transported to the non-U.S. stations by icebreakers and aircraft funded by the National Science Foundation. Foundation funded research projects are supported by the icebreakers in the course of travel to and between the installations being inspected.

Question. For the U.S., a continuing presence and active research program on Antarctic, is clearly in the national interest. Do you feel that an 11 percent increase in the research component of the Antarctic will enable it to function adequately?

Answer. There is also a 20 percent increase in the "Direct Science Support" element of the Operatons Support Program. These are costs that directly support science activity and would not be incurred if the U.S. were merely to maintain a "presence" in Antarctica. This element supports operation of research ships and icebreakers supporting research. Also included are costs which in most other NSF programs would be included as part of the research grants to the academic institutions. Examples are transportation to and from Antarctica, special personnel clothing and equipment, lodging, food and medical care while in Antarctica, aircraft support for research programs, field camp support, and laboratory and research equipment support. In summary, we believe that a sound program will be carried out at the requested level.

Senator GORTON. Dr. Good.

Dr. GOOD. Thank you very much. I will simply submit the written report in the record.

Senator GORTON. It will be included in the record.

Dr. GOOD. I will simply make a few comments at this point, but would be happy to address any questions that you might have.

First of all, I would simply like to make the comment that the influence that the National Science Board exerts over the actual intellectual program at the Foundation is done primarily by oversight review and extensive programmatic discussions between the Board and the staff, and long and detailed discussions with both the Director and the staff. I think in a sense that is perhaps the way that it ought to get its influence across and what the programs at the Foundation ought to be.

To give you a little bit of the kinds of things we have done recently, for example, I think a number of the members of this committee are aware of the problems we faced in 1981. We focused that year particularly on science and engineering education. The education question is a very difficult one for the Foundation to come to grips with, as you might suspect, because it is an enormous problem and an enormous activity.

And the question that we always have at the Foundation is what is the Foundation's role in that overall program, particularly for undergraduate engineering education. So we focused very clearly on that. I have some recommendations and we hope that we are moving toward a direction which will give the Foundation some guidance and some role in engineering, both in engineering research and also in engineering education.

We also focus on the social and behavioral sciences, the reduction in funds there. The question then was: What are the most important and what are the high priority items? And actually the Board had a great deal to do in its interaction with the staff and the Director as to the kinds of programs that we would be able to mount in those areas, and I think a great deal of attention was given to the priority items—those items that just really must be maintained. And I think the data base issue is one of those, and I think we have done reasonably well in doing that.

The other one during 1981 was research instrumentation. You have heard that, I suspect, by now so many times that you are tired of it, but unfortunately the problem has not gone away. Our universities are obsolete in equipment these days, and one of the real problems that you have in getting young people to come into the research areas of the universities is not just some of the things that have been discussed, but it is an atmosphere problem.

They can go to some of the industries and get clearly more state-of-the-art equipment to work with. This is particularly true in some of the engineering disciplines and some of the hard sciences. So we are back again, and we hope in this budget to improve the equipment problem as much as we can.

In 1982, again, there was special attention given to priorities in engineering at all levels and particularly in the graduate work. We gave some priority to plant sciences which we would be delighted to discuss with you a little bit, also computer-related research and international science.

Now those decisions were informed really by the flow of information which comes to the Board through a myriad of advisory committees, all of which are essentially free, I think. They also come from direct information that comes from the staff. We get an overview each year of all of the NSF-supported fields of science and engineering through the status of science reviews and then through long-range planning meetings.

And the Board, for example, is right now in the midst of a long-range planning review for the 1985 budget. We have already started on that and obviously it is a little bit difficult sometimes because you do not really know what you are going to get in 1984 before you have to decide what the priorities are for 1985. But one tries to deal with that the best one can.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF DR. MARY L. GOOD, VICE CHAIRMAN, NATIONAL SCIENCE BOARD

Mr. Chairman and Members of the Subcommittee, I am Mary L. Good, Vice Chairman of the National Science Board and Vice President and Director of Research of UOP, Inc.

It is my pleasure to appear before you this morning to discuss the role played by the National Science Board in the development of the fiscal year 1984 budget for the National Science Foundation and recent activities of the Board in areas of importance to U.S. scientific capabilities and national economic vitality.

The fiscal year 1984 budget states that Federal responsibility in R&D activities relates both to Federal needs, such as defense, and to broad national needs, where the Federal Government supports R&D that the private sector lacks incentive to invest in adequately. Support for basic research through programs of the National Science Foundation falls into this latter category, and such support has been targeted for substantial increase in fiscal year 1984. I support the high place that this Administration is providing for science and engineering in this budget.

ROLE OF THE NATIONAL SCIENCE BOARD

The National Science Board is charged by the Congress with a concern for the health of America's science and engineering capabilities. Working with the Director's senior staff, we spend a large fraction of our time each year attempting to balance priorities for NSF's research programs in a way that promises to strengthen both science and its contributions to the Nation. We are convinced that further advances in science and engineering knowledge are the cornerstone on which our military and economic security rest. We are pleased this year to support a budget that offers a balanced strengthening of all fields of science, while focusing especially on areas that are ripe for advance.

Each year, Board members have a series of formal and informal discussions with the Director and Assistant Directors of NSF and representatives of the scientific community about priorities in areas of science and engineering. In 1981 we focused especially on science and engineering education, on the social and behavioral sciences, and on research instrumentation and equipment. During this past year we paid special attention to engineering, the plant sciences, computer-related research, and international science. These discussions were informed by the flow of advice we get from NSF advisory committees, meetings of which Board members often attend. In addition, we receive an overview each year of all NSF-supported fields of science and engineering through the Status of Science Reviews report prepared in the fall and through long-range planning meetings held in the winter. We are in the midst of just such a planning sequence now.

Emerging out of our consideration of these many sources of advice is a series of recommendations for budget priorities provided jointly by the Board and the Director to the Administration. The Foundation and the Board, of course, work within the context of overall budgetary policies decided by the Administration and the Congress. We are delighted to support the Administration's budget proposal and look forward to your Committee's consideration of it.

Let me now take a few minutes to discuss specific areas of recent Board attention—science and engineering education, university-industry research cooperation, and science in the broader international setting.

SCIENCE AND ENGINEERING EDUCATION

In a policy statement issued in March 1981, the Board emphasized the need to focus available resources toward maintaining the strength of American science and technology; increasing the quality and sufficiency of scientists and engineers educated for careers in research, development, and engineering; and maintaining the U.S. position as a leader in international scientific and technological endeavors.

Thus, we put high priority on the key elements of our central mission, which we perceive to be support of science and engineering research performed primarily in academic environments to optimize both educational and knowledge benefits derived from a single investment. This priority continues in the proposed fiscal year 1984 budget, and I urge your support of both the level and distribution of that budget. It includes substantial increases for support of scientific and engineering research, thus contributing to NSF's unique role in keeping the sciences strong. It focuses on the educational context within which research is performed and future researchers are produced.

One critical skills problem that university support will not directly help solve, however, is the deterioration of math and science instruction in our secondary schools. Without quality science education activities that precede university-level activity, there would be no university-level activity.

In this area, the Foundation clearly recognizes that it must share responsibility with many others. The Federal Government, including other agencies as well as NSF, cannot assume responsibility for solution of the problem, since that responsibility truly lies with state and local governments. They can, however, indirectly aid or facilitate the resolution of problems surrounding precollege education. The Federal Government can play a leadership role, stimulating activity at the state and local level.

Two programs proposed in the fiscal year 1984 budget for NSF, aimed at improving the knowledge and skills of secondary school math and science teachers, will provide an incentive for other levels of government and private industry to attack the problems in pre-college science and math education. In addition, an initiative in the Department of Education will help state and local governments increase the numbers of math and science teachers.

The National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, which began its work last April, has done a superb job of outlining the problems—the declining achievement and participation in science and math at a time of increasing national needs, the lack of trained teachers for precollege math and science teaching, inadequate instructional time majority of students who will not themselves become scientists or engineers. Importantly, the Commission noted that public schools largely reflect, rather than determine, public perceptions and priorities, and these public attitudes have not always held math and science training to be of high priority for all students. Luckily for the Nation, those perceptions are beginning to change, and change rapidly. We see increased awareness, interest, and activity at almost every level and in all sectors. That bodes well for there being change in public attitudes so necessary if we are to offer all our students the kind of education that will enable them to participate fully in our highly technological society.

Between now and October, the Commission will work to define a national framework for improving math and science education at the elementary and secondary levels. The Commission will offer recommendations about the roles all groups and sectors—governments, professional societies, and the private sector—may play.

We will keep you informed of the Commission's progress, and we look forward to integrating into our work any recommendations the Commission may make with respect to an appropriate role for the Federal Government or for the Foundation.

UNIVERSITY-INDUSTRY RESEARCH COOPERATION

In research, as in education, no one sector has all the wisdom or all the resources. And, clearly, the sectors would benefit from greater intercommunication. The National Science Board has recently completed a series of studies on university-industry research relationships. Earlier this month the President sent to the Congress the report that we prepared based on those studies entitled University-Industry Research Relationships: Myths, Realities and Potentials. This report articulates the current set of relationships between research universities and private companies.

Those relationships bode well for the economic strength of the Nation. Private industry looks to our research universities for trained people and for the results of fundamental research in science and engineering, both of which are essential to the companies' ability to innovate and increase their productivity.

A bright spot in university-industry relationships is the collaborative research in which companies share their problems and talent with universities, and help faculties and students get experience with the most interesting industrial problems. This is a promising area which can bring the real world of industry into academia, and the creativity of the university environment into industry. Cooperation is growing rapidly, and we hope that our report and studies will contribute to an understanding of both the risks involved in such cooperation and the great potential benefits that it offers—to universities, to industry, and to the Nation.

SCIENCE IN THE INTERNATIONAL SETTING

Scientific research benefits not only from cross-fertilization among different performers within the United States, but also from the cross-fertilization that occurs by worldwide efforts to advance science. The United States, like many other nations, owes its scientific excellence to the cumulative growth of basic knowledge resulting from the openness of the world scientific community. U.S. science was nurtured early in this Century by sending some of our best young people to the great universities of Europe. In the 1930's, America provided a hospitable home for talented scientists who were refugees from tyranny and who brought with them the great intellectual European scientific tradition. With that important experience in international science and technology, the United States was able, after World War II, to lead a coalition of free Western nations in a scientific resurgence from which all nations have benefitted greatly.

The United States is, for many reasons, now at a critical point in its international scientific interactions. In his message to the Congress accompanying the 1982 Report on Science, Technology and American Diplomacy, the President summarized the situation at the turning point:

"We recognize that, while the United States retains international preeminence in many areas of science and technology, we are no longer in a position to dominate each and every field. Nor do we hold a monopoly on the world's supply of scientific talent. . . . Thus, just as the United States can profit from and be stimulated by vigorous international competition in science and technology, we can also profit through international cooperation, which extends and complements our own efforts and helps us achieve our national objectives."

It is just those dual aspects of competition and cooperation that the National Science Board undertook to study this past summer. The Board recognized the intrinsically international nature of modern science and the need for increased cooperation—ranging from planning for and building large research facilities to joint research on climatology, oceanography, geophysics, and other inherently global subject areas. The value of international scientific cooperation is by no means limited to the use of large facilities. Individual scientists in specialized fields often find international collaborative efforts to be of signal importance in facilitating the advancement of their fields. This Administration is a strong supporter of such international cooperation, and the the Science Advisor has taken a lead role in the follow-on talks called for in the July 1982 Versailles Summit.

Because of the important international dimension of modern science, the Board concluded that this dimension must be actively provided for in all Foundation programs, from education and fellowships to the various disciplinary efforts in the natural sciences, social sciences, and engineering. Planning for new facilities and the setting of priorities for major scientific investigations and programs should be carried out with the full recognition of the priorities of other countries and in an environment which encourages complementarity, cost sharing, and coherence of the various efforts of cooperating countries.

CONCLUSION

Mr. Chairman, I have appreciated this opportunity to appear before your committee to support the fiscal year 1984 budget for the Foundation. It is a strong budget, which promises a healthy infusion of both talent and ideas to attack the scientific problems that are most challenging intellectually and that will also contribute to our economic health and our national security. I urge your support of the budget before you.

[The following information was subsequently received for the record:]

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

Question. Recently the National Science Board released their annual report focused on university-industry relationships. Would you elaborate on the Foundation's role in the area of industry/university research?

Answer. The role of the Foundation in the area of industry/university research is reflected primarily through two programs, namely, Industry/University Cooperative Research Projects and Industry/University Cooperative Research Centers. The Industry/University Cooperative Research Projects program supports the advance of knowledge in scientific areas that underlie new technologies by linking the ideas, skills, and facilities of university researchers and industrial researchers in their common interests. It supports research projects jointly designed and implemented by industrial and university scientists and engineers. Substantial cost sharing by industry is required. All research support through this program is fundamental, nonproprietary, and of potential industrial relevance. The Industry/University Cooperative Research Centers program fosters industry/university interaction by supporting coherent programs of research at university centers on specific technologies with industrual relevance such as the manufacture of polymers, biotechnology, and chemical processing, among others. The centers are cofunded with industry at start up and are required to become self-sufficient in five years, as funding from the industrial sponsors gradually replaces NSF support.

Question. Would you comment on the Board's view of NSF's intention not to increase the number of research grants concomitant with the increased budget but rather to increase the amount per award? What is the implication for young scientists who are first-time applicants?

Answer. The Foundation intends to get the best return on the Nation's investment in research. Rather than provide less-than-adequate support for a greatly expanded number of research projects, the Foundation has chosen to maintain scientific excellence for a slightly increased number of projects. This is done by ensuring that adequate resources are available to pursue aggressively the most promising and exciting research opportunities. The increased support would provide for the acquisition of critically needed instrumentation, for the acceleration of existing and the initiation of new research thrusts, and for enhanced support for postdoctoral researchers and graduate students. The fiscal year 1984 Budget Request also includes $6.0 million for Presidential Young Investigator Awards to support research efforts of outstanding young faculty members for up to five years in scientific and engineering fields where demonstrated needs exist.

Question. Would you discuss the Board's timetable for selecting the Deputy and Assistant Director positions that are currently vacant?

Answer. The Deputy Director and the three Assistant Directors now being sought are chosen by the President with the advice and consent of the Senate. The NSF Act gives the National Science Board and the Director the opportunity to make recommendations to the President.

In December, Dr. Knapp and Dr. Branscomb sent a joint letter to scientific and engineering societies asking for suggestions of possible candidates for these four Presidential appointments. Many suggestions were recieved and are being reviewed by the Board and the Director. Recommendations for the Deputy Director position have been submitted jointly by the Board and the Director to the President. Recommendations for the Assistant Director positions will be submitted to the President early in the Spring.

Senator GORTON. Thank you very much.

I have probably an hour's worth of questions for the two of you and also the assignment to preside in the Senate in 10 minutes. So I will ask you one question at this point, and then submit the balance of my questions to you in writing. Senator Lautenberg has graciously assented to stay and will preside through all of the questions which he wishes to ask.

I will begin with the central issue that I would like Dr. Knapp to enlighten me on, and perhaps Dr. Good as well, because it relates to her last set of comments. How do you establish these priorities within NSF? How wide is the role of the scientific community in coming up with the priorities which you give to us in very neat and tabular form when you get here?

Dr. **Knapp**. Well, of course it is fairly complicated and the outside community really does participate very heavily in this process of setting the priorities. It does this in several ways.

First, each of the areas of research in the Foundation has extensive advisory committee meetings which go on to advise the leaders of our discipline areas in what the priorities within a given scientific discipline are. These committees typically meet twice a year, but many times they are in contact with the managers that we have within the Foundation. The chairman, anyway, of these committees are in contact.

The general feeling, and opportunities in the particular scientific discipline are put into the Foundation through this mechanism from people in the field and also from the pressure of proposals which come. That is, the most exciting areas of science usually generate the most pressure via proposals to be satisfied.

Then the staff itself does visit and does have travel and does visit our contractors, our grantees, and see what is going on in the field. And, of course, as I stated in my testimony, our managers are, to a fairly major extent, people who are scientists who come in for 1 or 2 years to act as managers within the Foundation, then rotate back to faculty positions in some university or an industrial position, but are not necessarily permanent Government employees. So at that level I think there is quite good interaction with specific scientific disciplines.

Then, at the next level of aggregation we have the National Science Board. We have myself and my staff and the Assistant Directors who head the major areas of science within the Science Foundation. We are in constant discussion within the Science Board and within the staff of the Foundation on which areas overall in science, such as plant biology as compared to some other sort of biology, for example, why there would be a special emphasis in this particular case.

In this case, with plant biology, there are new genetic engineering developments which make it look to us like in this particular area there is really a tremendous opportunity at this time, and we should take that opportunity. That is a priority which we have in our budget, which is generated by the perception that in this particular science there is a great deal of opportunity.

And then, of course, our priorities are set with discussions with OSTP, with the OMB and other people in the administration and we finally come up with a budget which we have prepared for you which we think is really, as they say in the business, I guess, bottoms-up. It really comes from the working scientists and is filtered a few times but I think gets, I think, a well-balanced program for the country.

Senator **Gorton**. Thank you very much, and I will submit a number of other questions to each of you and we would appreciate your written answers.

Senator Lautenberg, thank you.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR GORTON AND THE ANSWERS THERETO

Question. OSTP Assistant Director (Denis Prager) for life sciences has resigned. He has directed a project to review and coordinate agency regulatory policies dealing with carcinogens. What are your plans for replacing him in order to fill the needs for health and agricultural science policy?

Answer. My office has been actively seeking a qualified individual, with the appropriate technical background, to assume responsibility in health and agricultural science policies. These continue to be of high priority to OSTP.

Question. U.S. market share of value added goods in international trade has not kept pace with world growth in trade. What efforts or programs has your office conducted to enhance U.S. technological research promoting food processing, handling of agriculture goods, or related value added technologies necessary to promote U.S. goods in the world market?

Answer. OSTP has been working with agricultural scientists in government and universities to strengthen the science base for agriculture. My office has also promoted a stronger role for the private sector in applied research and technology development in food processing. I have stressed, and sought to implement, a stronger collaboration between universities, industry and government so that the results of our first class scientific research may be quickly turned into competitive products. To encourage innovation and the competitiveness of U.S. industry, my office has been involved in efforts to formulate tax policies favorable to R&D, to clarify antitrust policies and to simplify patent policies.

Question. Has your office maintained a liaison with U.S. trading agencies, such as the Office of the U.S. Trade Representatives, in order to access the science and technology needs that are needed to promote U.S. goods in world trade?

Answer. Through the Cabinet Council on Commerce and Trade, my office has been working with the U.S. Trade Representative's Office, the Department of Commerce, the U.S. State Department and other Federal agencies. The Cabinet Council recently conducted an assessment of America's competitiveness in high technologies. OSTP also assisted the U.S. Trade Representative's Office on the GATT initiatives.

Senator LAUTENBERG [presiding]. Thank you, Mr. Chairman—former chairman.

Dr. Knapp, you and I have a unique experience. I am sure it will not be recorded in the annals of history, but this is a first for both of us. You said this was your first before this committee.

Dr. KNAPP. That is right. We are both freshmen, sir.

Senator LAUTENBERG. I am more of a freshman than you. Your familiarization with the area that you work in is one that comes from lots of professional experience. Mine comes from having won an election.

The fact is, by way of background, as perhaps you will be able to tell as time goes by, my involvement in the company that I helped found was from the sales and management side, not from the technical side, and I would not want us to have a technological debate here. I think I would lose, but for now I am the chairman, and c'est la vie.

What I see is a bit of a contradictory policy. This extends perhaps the range of discussion here a little bit on the need for those trained in the engineering aspects of education, math and science and national policy that seems to me—and I am trying not to be partisan here because I would not have this chair if I acted as a Democrat; I am in the minority group here—that limits educational assistance to those students who seek higher education.

We see it very profoundly in the State of New Jersey, which has a fairly limited private higher education facility. A lot of our students go outside the State for their education. It is too bad, because I think your agency epitomizes the interest in the search in our country for more scientists, more research, ultimately resulting in, we hope, advancement with the human race and for our country generally.

It is also great to see that so little of the costs for your budget comes in the operational side. So much of it goes to the beneficiaries, the programs. That is also very good, and I think there is something to be learned from that in terms of cooperation between the academic, business community, and government. That is where we ought to come out.

When Dr. Keyworth was testifying, one of the things that I was interested in was what I felt, in fairness to him, he is without a chance to rebut, that is there seemed to be a much sharper delineation between that which was basic research and that necessary to encourage the business sector to pick up their part of the research.

With that as a statement, let me go on. You expressed that the authorization that you are looking for is one that satisfies you in terms of need, is that the case—within the realm of reality, I mean?

Dr. KNAPP. Within the realm of reality, it does satisfy us, yes, and I think that we see a period of the last, say, 10 to 15 years where, as Dr. Keyworth has said in other testimony, although not today, but testimony with which I agree, that the university situation, the university laboratories have grown "shabby" is his word, that we really have lost a great deal of our ability to do first-line research in some universities because of the decay of the instrumentation, the lack of focus on basic research in some universities over the last long period of time.

And to really rectify that and make the universities absolutely first-class places to do research and to attract people will take more than 1 year of an enhanced budget. It is long term. I think he said this morning he thinks this administration and the Government in a bipartisan way should make a long-term commitment to basic research in the country and particularly through the NSF and the universities.

Senator LAUTENBERG. He defined it as a Federal trust, I think. I agree with that completely. Well, you should probably sleep better at night. Some of the agency heads who have come here, have been trying to defend major budget cuts in very important areas. I found it a bit unbelieveable that they believed in their work, that they could not support additional funding.

But you should feel good about your request and about the fact that you are obviously getting support, certainly here.

I notice that the computer science and information sciences are pursued in various directorates. You have computer engineering, the engineering sciences and math, and the physical sciences group, information sciences with the behavioral sciences.

Does this makes sense? Is computer science a bit of an orphan child in these directorates? How do we manage to maintain a coordinated approach to computer sciences at NSF, given this organizational framework? Or should it be an adjunct to others?

Dr. KNAPP. Well, there are several—I will make a comment and I will ask Mary to comment on it too.

Computer science as a science is very, very new as a discipline. As you know, most of the traditional disciplines in science are centuries old. Computer science is a few years old, and as it has evolved different areas of emphasis which relate to computer science have evolved in different areas of other disciplines than the information sciences, for example, came out of the kind that is accorded in our BBS directorate came out of interests which were in other sciences in that directorate.

The engineering aspects of computer science, which are supported in the Engineering Directorate, are in fact associated toward the production of silicon chips, the new technologies and so on. Computer science, as supported in the mathematical and physical directorate of the Foundation, has in the past emphasized the methodical aspects—the development of software, algorithms and the use of the computer—but not the hardware that goes into the computers.

These in fact are fairly well coordinated within the Foundation and within the university departments which do this kind of research. However, it is very dynamic. It is not very old, it is still changing, and I am sure that before we are finished, in fact perhaps before I am through with my tour as the Director of the Science Foundation, we will have changed our organization to better match the way that the field of science which is just developing is developing itself within the university and within industry, for that matter.

I mean, the universities really in this case work quite closely with industrial firms and in all of these areas different aspects of industry—in all of these areas there are really quite nice examples of close cooperation.

Dr. Good. Yes, I might make a comment on that.

I think the aspects of it which Dr. Knapp has responded to are relatively straightforward. Computer science applications, the algorithm development, and so on in an atmosphere which is close to mathematics and physics makes a lot of sense and I think that is a good place for them to be. I think the more hardware and materials developments kinds of things in the engineering directorate is, again, kind of an appropriate place because you are going to get a lot of synergism between the other activities in that group.

The place where we get some difficulties, I think—and in fact the March board meeting will address this issue to some extent—where we get into difficulties is this whole concept of communications science and the whole concept of science information versus information science.

I sat on a panel for the Foundation about 3 or 4 years ago and the Foundation realized it really needed to come to grips with that issue. It was an enormously difficult topic. The community that came before that meeting was well chosen in the sense that it had representation from all of the various players. The problem is there is no consensus because the fledgling communications industry today, particularly the data bank operators and science, if you like what I would call the whole science information half, is today a pretty ongoing commercial adventure.

So you are then forced to go back and look at what can you do in terms of the information science part, and that is an area where I think the Foundation is in the process of trying to decide what it ought to do.

There are problems, for example, with the people interactions in that. How do you get people where you can really interact properly? What are the sociology problems? What are the psychological problems? There are some social sciences associated with it and then there is some hard science about how you actually put things together so that people can get the information out that they want.

But it is a difficult question and we are in the process of looking at that one at the moment and any input you have will be welcome. But there are lots of players and there is lots of discussion.

The Foundation early on, back in the middle 1960's, put a lot of money in science information and information science. They funded most of the basic research that was done, for example, for the development of on-line data bases. But once that is done, then you are back into the commercial arena and it is a little difficult to decide exactly——

Senator LAUTENBERG. Now it is a bit complicated. I was one of the purveyors of data bases in my former life, my civilian days, and we specialized, of course, in the commercial area generally, but we also had some engineering bases accessible to our network.

We specialized in economic data bases.

Dr. GOOD. If I could interrupt just one second, I might make a comment that there is a major need, however, for hard technical data bases, and the problem is that they are small and the users are small and they are not necessarily good commercial items.

Senator LAUTENBERG. They are not at all. That is true. What we found, for instance, in commercial information processing it was typified by large input-large output, relatively small computer requirements, as contrasted to engineering and science, where you have relatively small input requirements and a lot of computation of throughput processing and then fairly small outputs as well.

But it is an area of obvious interest to you and it is one, I think, that feeds so much of our other disciplines that at times I feel that it ought to get its own attention and at other times that it serves best when it serves another function. I mean, it is not there for the purpose of communications, communicating data and presenting information.

Someone made earlier reference to the sociological change in our society and that is one of the things that I would like in my term in this job to help address. There are going to be major social changes that people are not looking at, and I do not know whether you do it within the framework of the National Science Foundation. But how it is going to affect our lives educationally, in transportation, medically, treatment at home is going to be on a much different basis, with the doctor able to view the patients, make the prescriptions, examine the results, whatever they are.

In education for the handicapped we might not have to do as much transportation in the future and enabling them to participate in classroom discussions and things of that nature from home. That is a major social change.

One of them, of course, is the fact that the various spouses, whatever the plural of that is, might be able to do their business at home and not have to leave the house. I once said that on the campaign trail and a woman said does that mean my husband's going to be home all the time? I said he could be, in his business. She said, that would be terrible; I am not for that much advancement.

What did NSF request of OMB for each of the directorates? Is that fairly consistent with the overall increase in budget?

Dr. **Knapp**. Well, I was not the Director when the OMB request—I do not—I was not even in town when——

Senator **Lautenberg**. What is the result?

Dr. **Knapp**. When the request to OMB was made, but it is my understanding that the OMB in fact did not modify the priorities set forward by the Science Board appreciably—perhaps a few areas, but not drastically in any case.

Dr. **Good**. As I understand it, really there are very few major, essentially, no major shifts in priorities in that budget.

Senator **Lautenberg**. Well, I guess we are not at the stage where any one of these things is emerging as a substantially higher priority. They are all high priorities.

Dr. **Good**. Unfortunately, they are.

Senator **Lautenberg**. How about looking at longer range budget projections off for a few years—1986, 1987, that kind of thing? You must look at those. Do the numbers suggest a form of stability? What kinds of things are you looking at for funding in the future?

Dr. **Knapp**. I think that the Foundation, if it could know in advance what its budgets might be in the future, could do a very good job of planning for a stable future. Historically I think the Foundation and the country in science got into a great deal of difficulty in its universities by extrapolating the growth which occurred in science in the 1960's into the 1970's and thinking that it would continue and modifying the way it hunted its grants so that next year, when the increases came again like they had in the 1960's, they would be able to do some of the things which they had been putting off.

And that way of looking at the problem got us into the instrumentation difficulties that science and universities are in right now, because for 10 years in a row instrumentation which was necessary was put off because next year the Foundation will get a big increase in its budgets like it had in the 1960's and we will be able to take care of these problems.

I think that we can make science healthy in the universities and we can have a good program, but it really is necessary somehow to develop a mechanism for the Foundation's management and the Science Board to look forward into the future and say this is the level at which we should expect support and will plan a program then which has the right number of grants, the right amount going into instrumentation, the right amount of funds going into large facilities, so that we do not have to starve, if you wish to call it that, we do not have to cut back any segment of our work in order to modify our program because our expectations were not what the reality really has turned out to be.

Senator **Lautenberg**. Your interest in the programs of the NSF really do require a longer range look, and it is pitiful to have to negotiate each year's operating budgets. It puts you somewhat in the position that business is taking—which is a problem in our country today, of taking the shorter term view that we have to make our profits.

As a result, more and more research is being deferred in the interest of short-term gains, and that is too bad.

Unless there is anything else that you would like to suggest, that you would like to present here, I would ask only one favor of you, and that is, if either one of you would address me as chairman so it is on the record. I will have accomplished this on my first day as chairman.

Dr. **KNAPP**. Thank you, Mr. Chairman.

Dr. **GOOD**. Thank you very much, Mr. Chairman.

Senator **LAUTENBERG**. The subcommittee stands adjourned.

[Whereupon, at 12:15 o'clock p.m., the subcommittee adjourned, to reconvene upon the call of the Chair.]

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, MARCH 9, 1983

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1:15 p.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. Welcome to the second day of our hearings on the proposed budget for 1984 for the National Science Foundation.

At our hearing on March 3 we heard from Dr. George Keyworth on the administration's view of the Federal role in support of research and development, and from Dr. Edward Knapp and Dr. Mary Good on the programs and plans of the Foundation for 1984 and beyond.

The National Science Foundation supports research in almost every discipline at hundreds of colleges and universities. For 1984, the Foundation, in cooperation with the Office of Science and Technology Policy, the National Science Board, and the scientific community selected several areas, including plant biology, materials science, mathematics, mechanical engineering, and astronomy as areas of intellectual opportunity which would receive substantial increases in funding. We heard from our witnesses on March 3 that these areas and others have great potential to push back the frontiers of knowledge.

In addition, NSF has funded programs in university-industry cooperative research, and in research in small business innovation that have become models for these important mechanisms that can improve the Nation's overall research effort.

Today, our witnesses represent both the premiere academic and industrial research communities. Each of them will offer his perspective, not only on the plans and programs of NSF for 1984, but on the larger questions of the stability of Federal support for basic research and the changing nature of university-industry research relationships.

Our witnesses come from some of our great public and private universities, from two of the giants in industrial research laboratories in the Nation or perhaps the world, and from that distinguished body of scientists drawn from many disciplines, the National Academy of Sciences.

Senator Heflin, do you have an opening statement?

OPENING STATEMENT BY SENATOR HEFLIN

Senator **Heflin**. Mr. Chairman, I join with you in welcoming our distinguished guests here today for the continuation of the National Science Foundation authorization hearing. I am extremely pleased that we have Dr. Thomas Bartlett, chancellor of the University of Alabama Systems, as one of our witnesses. Dr. Bartlett is eminently qualified to tell us about the benefits of basic research. Before becoming chancellor of the University of Alabama Systems last year, he was president of the Association of American Universities in Washington. In this capacity, Dr. Bartlett organized and directed Federal relation programs on behalf of research universities.

Gentlemen, one area that I particularly am interested in exploring with you is the relationship that now exists among the Government, industry, and universities. According to the National Science Foundation only a small amount, perhaps as low as 1 percent, of every research dollar spent by universities in both the hard and soft science is supplied by the commercial sector. It would seem that we need a closer working relationship among Government, industry, and universities in order to better match educational resources with national needs. I will have a few questions regarding this later. I look forward to hearing from all the witnesses about the role basic research plays in the U.S. efforts to maintain its leadership in science and technology.

Thank you, Mr. Chairman.

Senator **Gorton**. Our first panel will consist of Dr. Frank Press, President of the National Academy of Sciences, and Dr. William Richardson, chancellor of the graduate schools at the University of Washington, who is representing several affiliated associations, among them the Association of American Universities and the American Council on Education.

First, welcome to Dr. Press and Dr. Richardson, and if they will come forward.

Dr. Press, welcome, and we are delighted to hear from you.

STATEMENTS OF DR. FRANK PRESS, PRESIDENT, NATIONAL ACADEMY OF SCIENCES, AND DR. WILLIAM RICHARDSON, CHANCELLOR, GRADUATE SCHOOLS, UNIVERSITY OF WASHINGTON

Dr. **Press**. Mr. Chairman, I will abbreviate my remarks to 5 minutes.

Senator **Gorton**. We will include your entire written statement in the record.

Dr. **Press**. I am pleased to present this very brief summary of my views on the proposed budget for the National Science Foundation and its role in the Nation's basic research endeavor.

I begin by commending the substantial increase in overall funding proposed for the Foundation. What is most heartening is that the President has endorsed an expanding research budget in the physical, mathematical, and engineering sciences in a climate of budgetary austerity. That endorsement will enhance the confidence of the scientific community in the Federal commitment to basic research.

Much of the credit for this achievement must go to the President's Science Adviser and to the new Director of the Foundation. However, I do have some concerns which I wish to share with the subcommittee.

One is the funding levels proposed for the National Institutes of Health. While the NIH budget is not at issue in this hearing, basic research is. As such, I think it wrong to reduce the NIH budget in real terms using its past growth as a rationale. The biomedical research created by the NIH budget is leading this country, indeed the world, through a revolution. We need real growth to sustain that remarkable progress.

I also have some additional concerns relating to the Department of Defense research budget and the proposed reductions in the budgets of several mission agencies. My concern with the DOD budget is what seems to be a steady and apparently systematic erosion of basic research. Specifically, funds intended to support basic research are being diverted by management decisions to tasks that do not normally fall within the accepted definition of basic research.

The consequence is that closer relations of the DOD with basic researchers are being placed at risk. I do want to emphasize that the problem is not the level of funding, because the category of basic research is going up. Rather, it is the definition of basic research and the diversion of funds into other areas.

This is not new with this administration. It is a trend that has continued over the past several administrations. Further, the administration has proposed reductions in the budgets of several mission agencies with strong research components. The administration has based its case with these cuts on its beliefs that these affect primarily applied research areas which should be taken over by private industry; but we do need to examine carefully the actual consequences of such reductions.

Despite such specific concerns, I must reiterate my general pleasure with the proposed budget. The OSTP and the Foundation have made earnest efforts to involve the scientific community in shaping this year's budget and are to be commended for that.

Finally, I would like to emphasize two principles that should guard the formulation of science budgets if we are to nurture the Nation's basic research system. These are stability and predictability.

I think the health of the Nation's basic research enterprise is so important that the Government should commit itself to a stable and real growth in basic research funds of about 1 or 2 percent a year.

The second tenet of predictability means that the research system needs adequate forewarning of changing Federal priorities if damage is to be continued. We must, for example, avoid severe and peremptory cuts which were inflicted on the social ences.

In my written testimony I discuss such issues as mechanisms for achieving stability and predictability, problems of the research universities today, the new issues of industry and university relationships, some lost opportunities from underfunding in research and so on.

But, Mr. Chairman, in view of the shortness of time, I have completed my oral testimony at this point.

[The statement follows:]

STATEMENT OF DR. FRANK PRESS, PRESIDENT, NATIONAL ACADEMY OF SCIENCES

Mr. Chairman, I am pleased to present my views on the proposed budget for the National Science Foundation and its role in the nation's basic research endeavor.

I begin by commending the substantial increase in overall funding proposed for the Foundation in fiscal year 1984. This endorsement by the President of an expanding research budget in the physical, mathematical and engineering sciences in a climate of budget austerity will, I believe, enhance the confidence of the scientific community in the federal commitment to the support of basic research. Much of the credit must go to the President's Science Advisor and to the new Director of the Foundation for the very strong and persuasive case they have made for strengthening the nation's scientific and technological enterprise.

However, I do have some concerns which I wish to share with the Subcommittee. One is the funding levels proposed for the National Institutes of Health. While the NIH budget is not at issue in this hearing, basic research is; and, as such, I think it wrong to reduce the NIH budget, measured by constant dollars, using its past growth as a rationale. The biomedical research created by the NIH budget is leading this country—indeed, the world—through a revolution. We need real growth to sustain that remarkable progress.

I also have some additional concerns, relating to the Department of Defense research budget and the proposed reductions in the budgets of several mission agencies.

My concern with the Department of Defense budget is what seems to be a steady and, apparently, systematic erosion of basic research. The difficulty is that while the funds for basic research—so-called 6.1 funds—have increased, the reality is that they have been partially diverted to support projects not falling within the commonly accepted definitions of basic research. For a variety of reasons, 6.1 funds have been flowing into applied research areas to support activities variously labeled as "thrust," "new initiatives," "special focus," and the like. The consequence is that the very laudable purpose of closer relations of DOD with scientists involved with basic research is being risked. I do want to emphasize that the problem here is not level of funding, but the actual uses of those funds. It should also be said that this erosion of the basic research capacity of the DOD continues a trend that began in preceding administrations.

Further, the Administration has proposed reductions in the budgets of several mission agencies with a strong research component—notably the National Bureau of Standards, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency. The Administration has based its case for these cuts on its beliefs that these affect primarily applied research areas which should be taken over by private industry. However, we need to examine carefully the actual consequences in providing the scientific foundation for industrial technology, environmental protection, weather and climate forecasting, and exploration, exploitation and preservation of our land and ocean environments.

One can argue that the "balance wheel" role of the Foundation's budget will dampen any cuts in the basic research programs of these agencies. Indeed, the "balance wheel" metaphor has served, since the 1960's, as budgetary argument for both adding or denying funds. Agencies have justified reductions by asserting that the Foundation will provide added support. Unfortunately, over the years "dropouts" by mission agencies were never fully compensated by add-ons in the NSF budget.

Further, while the balance wheel metaphor is sometimes apt, one needs to remember that in many fields of science and engineering, the Foundation's budget is not a balance wheel, but a pillar. NSF funds are 50 to 90 percent of the support for academic research in the geological sciences, mathematics, ground-based astronomy, anthropology, and ecology. Also, NSF funds provide 30 to 40 percent of the basic research funding for chemistry, economics, electrical engineering, and several areas of physics.

These and the other disciplines supported by the NSF, with the biomedical sciences supported by the NIH, are the heart of the scientific endeavor. It is in that light that the importance of the proposed budget for the Foundation should be seen.

What is heartening about the budget is not only its numbers but how it was shaped. Its formulation has been, with few exceptions, a collegial one, marked by earnest efforts in both OSTP and the Foundation to involve the scientific community. The National Science Board has continued its role in budget creation. The White House Science Council has had a major influence. The Academy complex—including not only the Academy of Sciences, but also the National Academy of Engineering, the Institute of Medicine, and the National Research Council—has provided advice about opportunities in major fields of science, when called upon. Some examples are the recent reports of the National Research Council on basic research in the social and behavioral sciences, astronomy, and the reviews just getting under way on chemistry, physics, and the earth sciences. Other examples are the series of research briefings, done at the request of OSTP, by our Committee on Science, Engineering, and Public Policy. Copies of the published volume of these briefings were made available to your Subcommittee.

In sum, I believe that there is now an improved discourse between the scientific community and those responsible for formulating federal science policy, notably OSTP.

With that setting, I would like to address several specifics relating to basic research, the Foundation, and the national utility of scientific progress. These are: (1) Achieving stable funding growth; (2) a perspective on the university-industry ties now becoming more apparent; and, (3) effective industrial exploitation of the national investment in basic research.

First, stability in funding. We have had, since about 1970, a cyclincal pattern of funding, with one gross effect, acknowledged in this year's budget, being an underinvestment in the mathematical, physical, and engineering sciences. Dr. Keyworth has already noted, in previous testimony, the more visible results—the inadequate state of many academic laboratories; the generally low salaries, particularly for support personnel; the frequently obsolescent instrumentation. The opportunity costs are impossible to measure. What did we not discover, create, measure, prove or disprove because the funds weren't there? We'll never know, but the new knowledge foregone must have been impressive.

However, prospect is more immediate than retrospection. And the prospect is exciting and demanding. It is exciting because I firmly believe that we are embarking upon a remarkable technological age, one of rapid progress and a cascade of new applications. In genetics, solid-state physics, cosmology, high-energy physics, the neurosciences and the other subdivisions of science, we are attaining a new level of understanding forming the base for technological leaps. Just as quantum mechanics seeded the computer and electronics revolution, so will the present discoveries seed a new one.

That is what is exciting. What is demanding is that other nations see the same vision and intend to reach it first. Japan's very ambitions and well thought-out fifth-generation computer project is one example; France's ambitious in biotechnologies another. Basic research will hardly be the sole determinant of national outcomes; technological innovation is too complex to be that simplistic. But I believe that excellence in basic research will be indispensable.

It is true that other countries, notably Japan, have done well without a strong research component. However, it is also true that these countries are learning the limits of derivative science. Indeed, Japan, France, West Germany and the other leading scientific nations have now commonly asserted the need to strengthen their capacities in basic research. It is quite likely that they will advance rapidly, if they back their principles with sufficient funding. Our problems are somewhat different and perhaps more difficult: that of incremental advances at the frontiers of science. To maintain leadership in the face of competition means higher costs as the needs for better and more complex instrumentation, training, new facilities all scale upwards.

To be successful in basic research demands a system that is flexible, that is well supported, that demands excellence of all whatever their reputations, that is not saddled with bureaucratic rigidities. Other countries use various stratagems to try to achieve that. As the Chairman knows, we do it in the United States by making the research universities the "home of science"—by firmly knitting education with training students in independent research. And it is the blending of the rigors of first-class teaching and research with the creative powers of students that pours out the new knowledge from which we all ultimately benefit.

Therefore, I agree fully with the argument made by the President's science advisor that "federal programs must emphasize the dual benefits of university research: the research and the students trained." What the system needs from the Federal government is stability and predictability: stability in the rate of funding growth and predictability in changed priorities.

Regarding stable growth, I have, in previous testimony and in an article in Science, proposed a mechanism for achieving such stability. It partly tracks present science policy in emphasizing a rigorous evaluation of the quality of developmental work supported by the Federal government and of the institutions doing that work. Such an examination would, I believe, free sufficient funds to enable a real annual growth of two percent in the basic research budget. In addition, I've proposed that industry commit itself to a real increase of about one percent of the total research funds now going to the universities. That would mean an annual increase of about $50 million to the sums industry is not giving.

I realize full well that to ask for stable growth in these times appears naive. But Federal funds for basic research in the coming fiscal year will, in the Administration's budget, be 14 percent of the total Federal R&D budget, less than 7 percent of the nation's R&D budget, and less than a percent of the total Federal budget of almost $850 billion. Does the government make any other investment that is proportionately so cheap and so immeasurably rich in its results?

I mentioned predictability as another tenet of Federal science policy. If there are to be changed directions—even reduced growth rates—then the research system needs some predictability if the damage is to be contained. To do less risks the career of some of the best people this country has: the men and women embarked on a career in research; it can tear apart the very fragile web within which research thrives. We now can acknowledge, I hope, that the severe and peremptory manner in which cuts in the social science budgets were imposed cost the nation dearly. I hope we can avoid a recurrence of that type of episode. Some of the damage is being repaired in the present budget; but funding for the social sciences has still not regained the pre-fiscal year 1982 levels.

If our goal is a highly productive and creative American science, then stability and predictability should be major principles in Federal science policy. The scientific community should be actively involved in advising on scientific opportunities, in developing methods for optimal distribution of research funds to maximize the returns, and, most importantly, in explaining to the public the value of science and the justification expenditures of public funds to strengthen science.

Now my second point: the relation of universities and companies. These relationships are not new; they antedate large-scale Federal entry into research. Moreover, the relationships formed in the 1920's and 1930's—between MIT and the chemical industry or between Cal Tech and the budding aeronautical industries—arguably drove those industries to world prominence. The nation benefited richly—economically and, in World War II, militarily.

I think we will someday look back on the links forming today and see that they blessed the nation, most especially in providing new and imaginative conduits between basic research and its applications. There are problems, to be sure. Public funds should not buffer private risks. However, the nation invests in basic research to, in time, gain economic advantage; and, therefore, the operative policy should be to catalyze rather than hinder university-industry relations.

That said, there are some facets on this issue of direct pertinence to the concerns of this Subcommittee. The first is perspective. By any measure, industrial investments in academic research are relatively small—about one-half of one percent of total spending on national research and development. Also, industrial spending directly on academic research has, in constant dollars, rested between three and four percent of total spending on academic research. Put another way, of the 200 leading research universities, only 25 received more than ten percent of their R&D expenditures from industry. Finally, a recent NSF projection of R&D spending through 1990 did not foresee any significant change in that level of industrial spending on academic research. In all, the Federal government is and must remain the major patron of basic research. Industry investments are not replacements for Federal support; they are narrowly-targeted supplements.

A second facet of university-industry relations deals with Federal policies whose adjustment or creation will quicken the transit time between basic work and its applications. There has been, to my knowledge, as yet no systematic study of governmental influences in shaping these new research cooperatives; yet the government—through its tax, patent, regulatory, funding, and other policies—is very much the silent partner in university-industry ties. One might well ask whether an examination of the collective effects of governmental policies in this area is needed.

A third aspect turns the previous one on its face: what are the responsibilities of industry and academia vis-a-vis the Federal government? The government is owed, rightly, an accounting of how its funds are spent, most acutely when industrial and governmental supports appear to commingle. This is not to advocate the bureaucratic nightmare of A-21, particularly in the way it is now administered. However, I believe that reporting requirements can be constructed to satisfy the legitimate needs of government without slowing research or violating academic freedom.

And, aside from accounting, there is the matter of open communication of research results. Can industry draw on its investments in academic research without compromising the open communications essential to world-class science? I believe it can, if care and good sense prevail.

Finally, my last point: the needs of industry if it is to effectively conduct and apply research and development. The above comments on university-industry relations obviously apply, as does my earlier commendation for the proposed NSF budget. The Academy last year organized a meeting in which leaders from industry—Exxon, Ford, IBM, and others—agreed what they most need from universities if they are to advance in the 1980's is trained people: men and women who have been trained in the advanced sciences, have learned the norms, and gone through the rigors, of research, have demonstrated their capacities for independent and original scientific work.

As such, the Administration's initiatives in direct support of young investigators will be vitally important to industrial advance. Specifically, the Administration's request for $6 million to support up to 200 Presidential Young Investigators Research Awards is an important first step, one that industry will certainly match.

Further, industry is now increasing its own support of research and development. That gain has been catalyzed by governmental policy. Venture capital funds available to start-up companies have virtually exploded, because of changes during the past four years in the rate of taxation on capital gains. The net effect has been innovative catalysis.

As a result of such policies and of a realization within private industry of its own weaknesses, we are now seeing, I believe, the first stages of an entrepreneurial renaissance. The Administration's proposed budget for the National Science Foundation will, if approved, be a major factor in sustaining that resurgence. What is needed in the year ahead is stable real growth and predictability in changing priorities.

Mr. Chairman, this completes my prepared statement.

Senator GORTON. Thank you very much, Dr. Press.

Dr. Richardson.

Dr. RICHARDSON. Thank you, Mr. Chairman.

My name is William C. Richardson. I am graduate dean and vice provost for research at the University of Washington, and I very much appreciate being invited to testify today.

This is my first appearance before you, and in addition to the University of Washington, I represent the 50 universities which comprise the membership of the Association of American Universities, plus, as you noted, Mr. Chairman, a number of other higher education associations, including the American Council on Education, the Association of Graduate Schools, the Council of Graduate Schools in the United States, and the National Association of State Universities and Land-Grant Colleges.

As members of this subcommittee well know, this group represents virtually all of the universities and colleges in which federally sponsored research is carried out.

In this brief summary I would like to touch on four areas that I think are crucial for the committee's consideration. Dr. Press has emphasized the first; and that is, the need for stability.

Universities are such complex and multimissioned institutions and human resources are at such a premium that to have ups and downs is very difficult and very counterproductive. I think the social science example in my written testimony is a good one.

Going beyond the issue of stability, though, there are other areas of concern of serious magnitude. I, too, would like to commend those who have been involved in this year's budget proposals, not only the administration but beyond that, within the Senate, that begin to recognize what have become very serious problems indeed.

One, of course, is the instrumentation and facilities problem. The replacement of obsolete instrumentation alone is estimated at being in the neighborhood of $2 billion for university research. While we are trying to encourage basic research to support future economic growth, and indeed, the development of the country and its productivity, it seems ironic that our universities, which should be on the cutting edge, are in fact well behind industry in terms of their instrumentation.

The most recent AAU study suggests in fact that obsolescence is about two times as great in the university setting as in industry. At the same time, the cost of equipping a faculty member is very substantial, perhaps five times today what it might have been 10 years ago; and in some fields such as chemistry just the basic tools that one needs in order to carry out one's work run in the hundreds of thousands of dollars.

The environment is the second factor; that is, those tools are today computer related and highly complex. With the increase in instruction in the sciences and engineering and the change in instrumentation, there are very substantial facilities needs.

The third concern would, of course, be human capital. Any program of basic research recovery needs to provide major support for graduate students, for post-docs, for young scientists; and again, it is very pleasing to see that this problem is being recognized both in proposed authorizing legislation as well as in the proposd budget.

It is especially important, I think, to increase the number of stipends. We have gone from 50,000 down to fewer than 10,000 in the last 15 years. AT NSF, for example, down to 1,500 for a total of about 500 new starts. And both the level of these fellowships and their number are crucial if we are to maintain the kind of leadership we need to within our universities.

Lastly, the university-industry relationship is one that at the University of Washington feel is very important. Not so much that is represents funding that will in some sense offset or even in any very major way supplement what is fundamentally a Federal responsibility, but more in the quality of the relationship and the work that can be done collaboratively. In Seattle, as the chairman I know is aware, we have a consortium of five companies and the university in the computer science area that is very exciting.

Thank you. I would be pleased to respond to any questions.

[The statement follows:]

STATEMENT OF DR. WILLIAM C. RICHARDSON, CHANCELLOR, GRADUATE SCHOOLS, UNIVERSITY OF WASHINGTON

Mr. Chairman and members of the committee, my name is William C. Richardson and I am Graduate Dean and Vice Provost for Research, University of Washington in Seattle. I very much appreciate being invited as a member of the academic community to present views and information on: the importance of basic research to the future welfare of our country; the appropriate role of the federal government in support of basic research (and in particular the role of the National Science Foundation); future needs and priorities for support from various sources for the research enterprise; and a perspective on the appropriateness of and potential for collaborative university-industry initiatives in basic research.

This is my first appearance before you. In addition to the University of Washington, I represent the 50 universities which comprise the membership of the Association of American Universities plus the following higher education associations: the American Council on Education, the Association of Graduate Schools, the Council of Graduate Schools in the United States, and the National Association of State Universities and Land-Grant Colleges. As this Committee knows well, these associations together represent essentially all of the nation's universities and colleges which carry out federally sponsored research and related education.

In my remarks today I will at the outset comment briefly on the fiscal year 1984 budget request for university research and related education programs of the National Science Foundation. In the remainder of my testimony I will first elaborate on the fundamental importance of the growing recognition that the future economic health and security of our nation depends on the vitality and effectiveness of our research enterprise. Second, I will list and describe several major problems that have been allowed to develop in recent years which jeopardize our future effectiveness in this area. Third, I will describe the University of Washington's view on university-industry collaboration, with particular emphasis on the important role that the federal government can play in promoting this relationship. Throughout my remarks, I expect to comment on a number of recent initiatives.

GENERAL COMMENTS

To begin I wish to emphasize that the fiscal year 1984 budget request for the National Science Foundation is a strong step in the right direction. After a period of prolonged erosion in the research base of the nation, we are just beginning to see, at least in selected areas, the kind of national commitment to excellence in basic science and graduate education that we believe to be absolutely essential to the long-term economic vitality, security and well-being of our people. Government-wide much remains to be done to strengthen our investment in science and related education programs, but here, in the fiscal eyar 1984 budget request for NSF, we see an excellent first step. We particularly commend the Foundation for the strong commitments proposed this year for most basic research programs in the sciences and engineering. We note, however, the continued weakened position of the social and economic sciences, which remain budgeted at below fiscal year 1981 actual levels. (In the fiscal year 1984 proposed budget, one also sees continued serious erosion of biomedical research support, as well as basic research support in other mission-oriented agencies.) The NSF initiatives proposed to strengthen opportunities for young faculty, to renew the graduate fellowship programs and to increase substantially the Foundation's investment in research instrumentation all deserve the support of the scientific community and, we hope, the support of the Congress. The merits of the proposed initiatives are best assessed in the context of the vitality of university research and education programs, of their unique contributions to the nation and to the national investment that is required in the programs carried out in the laboratories of our universities.

THE PROBLEM

In just the last two years there has been a broad-based and growing recognition that the United States must revitalize its commitment to basic research in the physical, natural, and behavioral sciences, not only on the federal level but at the state level and in the private sector. For a number of years preceding this recognition, there had been growing concern in the scientific community and in industry about the neglect of adequate support for research training, facilities, and instrumentation. But acknowledging the importance of basic research to our society and recognizing, on a broad scale, its perilous state, are relatively recent developments. Concern about both the economic welfare of the country and its defense has heightened this awareness. Of course, basic research is essential for technological innovation, but never sufficient in and of itself.

Because results of many different research studies are combined in any practical innovation, it is very difficult to compute the economic benefits of individual research studies. It is, however, possible to obtain reasonable approximations of the economic benefits of larger research programs or of the efforts that were later combined to produce an innovation or a group of related innovations. Many studies over the years of the economic payoff of basic research have shown evidence of handsome rates of return to society. It is very important to note that returns to private industry are generally smaller than returns to society as a whole. This is so for two reasons: first, because the later benefits may spread over a variety of fields of application, some of the benefits cannot be captured by the particular firm or industry that supported the research; and second, savings—as distinct from increased sales—accrue to the users of innovations as well as to the developers. For example, although IBM and others have profited from their own and other research that made possible high-speed computers, the users of those computers have also experienced reduced operational costs and other benefits. These observations typically form the rationale for the major public, and particularly federal, commitment to the funding of basic research of all sorts.

In recent decades, the United States has been falling behind in its support of basic research, and the signs have been visible of a degree of shortsightedness in policy and often erratic patterns of funding. In the 1950s, the United States was primarily responsible for 75 to 80 percent of all major technological innovations developed in the U.S., the U.K., West Germany, France, and Japan. In the 1970s, the U.S. percentage declined to between 50 and 60 percent. To cite another example, while in 1965 U.S. scientists wrote 42 percent of the world's literature in physics, by 1977 they accounted for only 30 percent. In engineering, the decline from 1965 to 1977 was from 50 percent to 40 percent. In biology, the earth sciences, and psychology there have been smaller declines.

POTENTIAL STRENGTHENING OF NATIONAL SECURITY AND ECONOMIC PRODUCTIVITY

Technical innovations (jet engines, hybrid grains, microelectronic computers, input-output analysis in national economic planning, etc.) and major medical advances (polio vaccine, antibiotics, cardiac surgery, etc.) practically always result from the confluence of results obtained in two, three, or more different fields of research. After an innovation has been achieved (or has been clearly foreseen) it is possible retrospectively to identify most of the critical findings that led to that innovation. But prospectively, it is difficult or impossible to foresee all the outcomes of a research study. Even in the field of military weapons, a Department of Defense study of the utility or research found that a significant fraction of the findings that led to improvements in missiles, torpedos, a satellite, and other weapons were not anticipated at the time the Department let the developmental contracts for those weapons.

Nevertheless, there is a wide range of disciplines and research programs that can be seen to have a direct bearing on national security and U.S. economic productivity over the next decade. Many of these lines of research are summarized in the NSF publication, The Five Year Outlook: Problems, Opportunities, and Constraints in Science and Technology, Volume I (1980).

To cite a few simple examples, military and industrial activities rely on supplies of nonfuel materials drawn from uncertain foreign sources. Research leading to the development of high-strength polymers and ceramics, or the use or organic materials extracted from domestic plants may alleviate foreign dependence.

World food supplies, and in particular the productivity of U.S. agriculture, is a factor of vast strategic importance. Advances in plant tissue culture and recombinant DNA research are the basis for major new improvements in agriculture.

In the area of biomedical research, we can recall that only a few decades ago, the U.S. faced a clear choice with respect to meeting the challenge of recurring epidemics of polio. Simply stated we could either spend huge sums of money to make more and/or better iron lungs and prosthetic devices, or spend the relatively small amount of money to do the research needed to cure the disease.

We now face a parallel situation with respect to the need to develop a cost-containment strategy for the spiraling commitments of federal money to combat brain-behavior diseases such as depression and drug and alcohol addiction. In the particular cases of depression and addiction, there is good reason for confidence in the expectation of substantial breakthroughs if only the needed resolve to support research can be sustained through the next decade.

Many other examples could be cited ranging from electronics to cardiovascular disease. However, the country's security, economic progress, and even its efforts at cost containment in areas such as health care are threatened by major problems developing in its scientific enterprise. Among the most critical of these are:

The lack of a reliable and long-range federal commitment to fundamental research in the full range of disciplines;

Inadequate or obsolete scientific instrumentation and facilities;

Diminishing opportunities to attract and provide adequate support for graduate students and young scientists; and

Under-developed relationships between university research, regional economic development activities, and industry.

THE NEED FOR STABILITY

The collaboration in recent decades between the federal government and the country's research universities has been fruitful, and indeed is the envy of the world. As we consider our future it always is good to reflect on the nation's history. It was the sudden dependence on university-based science and scientists during World War II that let to a major emphasis on federal support for university programs of research and graduate training. The successful launching of Sputnik produced a new surge of federal interest in research and advanced education as components of a natural effort to regain and sustain American scientific and technological superiority.

The nation's universities, however, are complex, have several missions, and are labor-intensive. The importance of stability in funding in a university setting cannot be over-emphasized. A university, by its very nature, must be able to do some long-range planning, and must therefore have a reasonable basis for carrying out such planning. Further, bright students are not attracted to programs where future support and stability is uncertain or unknown.

The negative effects of instability in NSF funding on university researchers themselves is most notably illustrated in the recent changes in funding for the Division of Social and Economic Science. In fiscal 1980, the programs of this Division made awards totaling $31.3 million. This amount dropped to $17.6 million in fiscal 1982, a drop of approximately 44 percent. Even after a small upward adjustment for the current fiscal year, the amount available for the support of research in several social science disciplines, including economics, sociology, management science, and political science, as well as support for major and important data resource projects for the social sciences, remains some 36 percent below the fiscal 1980 level.

With such sudden shifts in the availability of research funding, investigators at the University of Washington, for example, (and I'm sure on many other university campuses as well) begin to question whether it is cost effective to do the substantial work required to prepare a proposal. The impact is demoralizing, and a great deal of time is wasted in efforts to adapt to such shifting levels of support. It is a waste of human resources when we impose such burdens on university researchers, and it is especially lamentable when one recognizes that such instability is based on short-term and ill-advised judgments. For example, in the case of the social science research budget cuts, the President's science advisory noted that these budget cuts displayed "poor judgment."

Stability and a long-range perspective are essential in all areas of science. This is not to suggest that there should not be gradually phased increments or decrements to various research programs or strategies as our body of knowledge changes and the opportunities shift. What it does suggest is that the current excitment over science and particularly high technology, while attractive in drawing attention to serious problems, should not be the stimulus simply for a quick fix. A sudden, one-time infusion would be as lamentable as precipitous and ill-conceived budget cuts. What is needed is a longer-range, sustained and very substantial commitment to the research enterprise.

INADEQUATE AND OBSOLETE SCIENTIFIC INSTRUMENTATION AND FACILITIES

There has been a general awareness in recent years of the increasing and dangerous obsolescence of scientific instruments and their physical environment, along with problems of instrument operations and maintenance. Many articles have appeared, reports have been written, and some modest progress has been made with respect to new appropriations. I say modest advisedly, since the estimates of needs range upwards to $2 billion, while the most notable new appropriation, apart from increases proposed in this year's administration budget, is the Department of Defense program of $30 million per year for five years.

To put these figures in local perspective, if the University of Washington, which as you know competes very effectively for federal funds, were to get its "share" of the DoD appropriation, the amount would be in the several hundreds of thousands of dollars. The detailed and I must say well-justified requests from the sciences and engineering at the University of Washington that were sent forward the first year for this program alone added up to $12 million of proposals for federal funding (plus a state match). Put another way, we could have wisely used 15 to 20 times the share of the equipment money that will be made available through this Department of

Defense program. Instrumentation, then, is a serious problem both with respect to supporting basic research and in the training of graduate students.

Two points documented in reports published in recent years by the Association of American Universities are particularly noteworthy. First, the AAU report of 1980 compares the age of research instruments in universities and in industry. Whereas 50 percent of the instruments in industry were less than 3.5 years old, that number was twice as large, seven years, in universities. In other words, roughly half the equipment in universities is twice as old as that in industry. This three and a half year difference is itself in many cases equivalent to the state-of-the-art useful lifetime of much scientific equipment. For industries to remain competitive, it is inappropriate for students to be trained on obsolete equipment.

A second important point emerging from these reports is the tremendous increase in the cost of adequate instrumentation to undertake modern day research. Capital costs have doubled or more over a recent five-year period. Over a ten-year period, from 1970 to 1980, the evidence suggests that the cost of providing adequate equipment for a new faculty member in a research-oriented chemistry department increased more than fivefold. Beyond this, in many departments such as chemistry, methodology has changed in such a way as to make these sciences truly high technology enterprises. Many basic tools required for a wide range of faculty and graduate students, those that are standard items, cost in the hundreds of thousands of dollars each.

On the other hand, these instruments have greatly increased the productivity of our research faculty and graduate students. Work that might some years ago have required two or three years of laborious effort can in some cases now be accomplished in a matter of weeks. Indeed, there are numerous examples where ingenuity together with outstanding equipment has led to major advances of knowledge. At the University of Washington one could cite examples across a range of departments. So while the rate of obsolescence is high and the capital costs are very substantial indeed, improvements in productivity make such investments cost-effective and absolutely essential if we are to remain in the forefront of research as it contributes to our national economy and security.

Althouth scientific instrumentation needs are ordinarily assumed to apply to physical sciences, for example, but not necessarily to social sciences, the fact is that there are increasing instrumentation needs—particularly needs for computer equipment—in all fields supported by the National Science Foundation. Research in mathematics once proceeded without equipment, and some still does. But increasingly such work is made more effective and efficient if assisted by a computer. In a similar way, work in the social and behavioral sciences, which once proceeded with few equipment needs, is not such as to require substantial investment in computer and computer-graphics facilities if the work is to be done efficiently and in a cost-effective way. Of course, instrumentation alone does not produce researce progress. As will be noted below, and as Congressman Walgren has stressed in a recent request for a report on the relative needs for instrumentation in different fields of science, the Congress needs to assess how the underlying intellectual needs—not only the instrumentation needs—of the several scientific areas are being met.

Beyond the need for instrumentation in basic discipline departments in the physical, natural, social, and behavioral sciences, there is a problem of inadequate and outmoded facilities and equipment required for high quality undergraduate and graduate education and research in our colleges of engineering. There has been a great deal of pressure in resent years to expand the capacity of engineering colleges and an enhanced awareness of the importance and value of engineering to society and particularly an awareness of the natural interdependence between healthy progressive engineering colleges and healthy dynamic industries.

There is a serious need to expand engineering facilities, but there are significant problems in recruiting, retaining, and providing the necessary environment for graduate students, particularly those in doctoral programs. Substantial long-term expansion of the capacity of engineering colleges to produce well educated engineers, on a par with nations with whom we compete, requires a greatly increased infrastructure. Engineering research, a vital element, represents slightly less than ten percent of NSF's budget. Increases proposed for fiscal year 1984 have been roughly proportional to other proposed increases in the NSF budget. It has been argued, however, that funding from NSF and other federal sources should recognize the substantial increases in the demands being placed on colleges of engineering which would suggest that still more substantial increases are appropriate.

For example, beyond the instrumentation needs cited for a range of sciences, displacement of space that can be used for research purposes from existing buildings to accommodate expanded instructional activity would require significant new research space on university campuses. Such new facilities could be constructed or older facilities remodeled to accommodate new and updated instrumentation. Such support for capital facilities is an appropriate federal responsibility, although a matching program with state and private sources should be feasible in a professional field that is of obvious regional and local benefit.

To summarize, the problem of obsolete instrumentation and the need for modern facilities to house the complex and sophisticated equipment and systems of the current and future decades is an urgent problem and one that is not going to be solved by a one-time infusion of funds. There is an enormous inventory problem for capital equipment which is continually aging and losing its effectiveness. The problem could be viewed as similar to the deteriorating transportation infrastructure, such as our roads and bridges. We can short change the system for awhile with no immediate, drastic consequences. But the effect is insidious, and when the cumulative deterioration finally reaches crisis proportions as it now has, there becomes a need for major investment as oppposed to modest or incremental federal support programs.

It has been suggested by some that universities should engage in more debt financing to acquire major instruments. There are certainly cases where this may be a valuable approach, but such an approach does not create new funding and simply provides a mechanism for diverting funds that would other wise be allocated for operations and personnel.

A $2 billion commitment by the federal government over a five-year period for a basic rebuilding of university research instrumentation would greatly strengthen this country's research productivity and its impact on the national welfare over the remainder of this decade. The largest share of such funds would most productively and appropriately be awarded on a competitive basis, using the very effective peer review mechanism that has served American science so well over the years.

In my own judgment, however, some fraction of such funds might well be used in a "capacity building" fashion. There are a number of states and indeed some regions in which the level of basic research activity is limited. At the same time, there are areas of economic development related to natural resources, historical developments, transportation considerations, and so forth, which suggest that a capacity-building investment with the concurrence and collaboration of state governments and industry would have a long-range payoff in the economic development of the state or region. One could imagine fruitful work in such diverse areas as feedstocks, biotechnology, very large scale integrated circuitry, robotics, and composite materials that would match the particular developments of certain states or regions. Surely the states themselves and local industry and universities could be inventoried in such a way as to estimate the approximate potential for capacity-building investments in scientific instrumentation. These capacity-building funds might well be distributed to the states according to a formula which would recognize the potential for economic development on the one hand and the lack of existing resources on the other. As noted above, one would not want to invest a large fraction of funds in this way if we want to get a maximum return on basic research over the next several years. If does seem an appropriate approach, however, for some fraction of the funds.

SUPPORT FOR GRADUATE STUDENTS AND YOUNG SCIENTISTS—AN INVESTMENT IN HUMAN CAPITAL

Another fundamental element of any program of basic research recovery in this country would certainly need to address the problem of providing sufficient support for advanced graduate students as well as research support to scientists at the very beginning of their careers, including post-doctoral fellows and junior faculty. It is difficult to attract and retain junior people engaged in basic science activities. The lure of applied work in industry is substantial, at the same time that the demand for regular faculty positions is quite limited. It has been estimated by the National Science Foundation that in 1979 there was 86,000 individuals engaged in faculty positions in science and engineering. The scientific and engineering faculty shortage estimated by the Scientific Manpower Commission is approximately 12 percent, suggesting that an increase of at least 8,000 young scientists would be desirable. An expansion of basic science support would, of course, further increase the need for scientific personnel throughout the economy. Further, the national forecast of faculty retirements between now and about the year 1995 shows a fairly slow, steady rate with a substantial surge in retirements between approximately 1995 and 2010. Thus, there will be a burgeoning of positions for which there is likely to be an inadequate supply of faculty by the year 1995. If corrective actions are not taken now, we can predict with certainty a massive national faculty recruitment effort beginning in the 1990s from a resource pool that is limited in both quantity and quality.

For many potential graduate students the increasing costs of higher education have made the decision to enter graduate school either impossible or simply imprudent. From Autumn 1980 to Autumn 1982, graduate tuition at the University of Washington, for example, increased 120 percent for resident students and 54 percent for non-residents. Tuition effective Autumn Quarter 1983 is projected at $1,890 (resident) and $4,692 (non-resident), making the percentage increment over a four-year period 145 percent and 71 percent for residents and non-residents respectively. In many disciplines, the prospective graduate student sees graduate school as an economic liability with poor chances of eventual payoff compared to alternative opportunities in industry. The result is our fear that the very best intellectual talent will not go on to earn doctoral degrees in the decade ahead, thus seriously weakening the researcher/educator pool upon which future excellence in higher education and science depends.

Although the lack of academic jobs in many disciplines threatens the supply of students who will enter academic careers in the future, the abundance of jobs in certain others is rapidly reinforcing the same problem. That is, in certain areas of biology, chemistry, mathematics, geology, geophysics, and in computer science generally, the job market is so fertile that earning a doctoral degree and entering an academic career is non-competitive for the prospective students. In some fields such as genetics, what began as an esoteric laboratory science has now given rise to a promising and rapidly growing industry. Molecular geneticists at the Ph.D., M.S., and B.S. levels are being hired in large numbers by both newly formed companies and by established chemical and pharmaceutical companies wishing to enter the field.

The situation in computer science is even more extreme. A report in 1980 submitted by the Computer Science Forum estimated that the supply of new Ph.D.'s in computer sciences is about 15 percent of the demand. Moreover, the Chronicle of Higher Education reported two years ago that salary offers in industry for computer scientists had risen 40 percent over a three-year period. This is an increase that universities simply have not been able to keep up with.

The fact is that expanding private sector career opportunities in certain fields have made earning a Ph.D. less attractive or alternatively in some cases have made it of such great value that an academic career has not sufficient competitive appeal.

The negative educational and economic effects of limited faculty career opportunities in higher education are certain. Evidence of these effects is likely to emerge slowly, however, as the legacy of a gradually increasing faculty mediocrity. The ultimate effect will be a weakening of research and instruction in higher education nationwide. In some fields, particularly in those outside the sciences, there may be a threat to the very continuity of scholarship. In other fields, particularly in certain areas of science where private sector careers are burgeoning, the limited attraction of faculty careers will serve to weaken research and thereby cut the lifeline that sustains industry's future growth. Both industry and society more broadly will ultimately suffer tragically from a long-term failure of academic leadership in both scientific and non-scientific disciplines. Industries depend heavily on the sciences for basic instruction and basic research that supply and continue to fuel their human resource pool and that make the discoveries upon which future products depend.

In responding to the competition there is a natural tendency for industry to focus on near-term rather than long-term solutions. The near-term measures attend principally to increasing the quantity of students being graduated and to focusing on certain fields of science and engineering. While this helps to solve today's human resource problem for industry, it does not solve the problem of tomorrow's leadership and creativity which depends on the quality of individuals who are furthering knowledge and who are providing instruction at the graduate level.

Again, it is gratifying to see that this problem is gaining increasing attention and indeed there is specific attention focused on this year's NSF budget to the human resource research training problem. It is important to note that we are not talking here about the broader need in society for scientific and mathematical literacy. Rather, it is the very basis on which future international competitiveness and economic development depend. To give an indication of the level of neglect in the last decade and a half, the number of federally funded fellowships has declined from 51,000 in 1968 to fewer than 10,000 new and continuing fellowships in 1983. Of the 1983 number, only about 1,500 were science and engineering fellowships through the National Science Foundation, with another approximately 4,800 fellowships under the Department of Health and Human Services' National Research Service Awards.

The Department of Defense through a new program offered an additional 66 fellowships in engineering.

Current serious deficiencies in graduate education should be addressed through several vehicles. First would be through an expanded program of merit fellowships. The size of stipends should be determined on the basis of realistic recognition of competing market forces. The new program mentioned above initiated by the Department of Defense is exemplary in this respect, providing stipends of $12,000 per year. Both fellowships that are awarded to individual students for study at an institution of the student's choice, and programs of fellowship support that are competitively awarded to academic departments are highly desirable. The National Science Foundation, for example, should establish a program allocating institutional fellowships to strong departments in the sciences and engineering. Other major research and development agencies should also establish institutional fellowship programs to support advanced training in areas of basic research broadly related to the mission of each agency. To be effective, such institutional fellowship programs must be allocated strictly on the basis of merit. There are a variety of mechanisms and criteria that might be employed.

Another critical vehicle for graduate student support which also directly benefits basic research sponsored by the federal government is adequate funding for research assistantships as a component of peer reviewed faculty research project grants. The research assistantship is the principal instrument for implementing the enormously valuable and distinctively American link between the conduct of research and the training of researchers. While providing necessary financial support for students in return for useful work, it provides the most direct and sophisticated research training for the nation's future investigators. And the infusion of the fresh perspective of bright, young students brings innovative vitality to American academic research.

Federal agencies traditionally have recognized the importance of advanced training as a component of federally funded research. For example, NSF, NIH, and other mission agencies have strongly supported the use of graduate students as research assistants. However, short-term perspectives and inadequate increases in basic research funding have begun to erode this important mechanism for involving graduate students intimately with faculty research.

UNIVERSITY-INDUSTRY RELATIONSHIPS

Finally, let me turn to the role of industry, and the importance of effective collaborative relationships between universities and industry. I should say at the outset that as important as industry's financial contributions are to the welfare of the nation's universities, it would be impossible for even the most dedicated and profitable array of companies to substitute in any consequential way for the financial commitment of the federal government in support of basic research. Industry as a whole is not inclined to such support and the magnitude of the dollars is simply insufficient. In a variety of professional areas, as well as in certain science disciplines, local industrial support for faculty summer activities, for supplementation of faculty salaries and for individual research that is expected to be of direct benefit to a firm are all important enhancements, particularly when industry is in competition for scarce highly educated personnel.

The more important and perhaps exciting potential in the involvement of industry with research universities, however, comes from the increasing recognition that technology transfer is real; that the number of fields in which university research can be translated relatively quickly into improvements in productivity or product lines is increasing; and the benefits to faculty and students in many areas from the exchange of information between industry and university settings are growing.

Federal support of faculty and graduate student research can be enhanced and its benefits maximized through close collaborative programs between industry and universities. Federal programs, such as found in the National Science Foundation, that provide additional stimulus through special funding of competitive research proposals that involve joint university-industry projects should be encouraged.

Various arrangements could be developed through consortia for shared support of research projects and shared support of and access to special research instrumentation and research facilities. This could be seen as particularly benefiting smaller and younger companies. Such cooperative industry-university efforts can be greatly facilitated through the development of high technology centers such as the one that is in the formative stages in the State of Washington, as well as those in other locations around the country.

In addition, the existence of such cooperative projects and mechanisms would greatly enrich the research environment for faculty and graduate students in colleges of engineering, as well as certain science departments. This would occur through participation of outstanding industrial researchers with strengths complementary to those of university faculty. Industry researchers could supplement the teaching program in their areas of expertise as well.

The University of Washington has had some recent experience in such a development which involves the participation of five local companies and the University's Department of Computer Science. I would like to describe this consortium in some detail for the Committee.

One of our faculty members had been offering courses, primarily for industrial clients, on the design of integrated circuits. These intensely practical courses gained considerable popularity, and were offered nowhere else in the region (and, indeed, in only a few places across the country).

Several companies wanted to make additional efforts to enhance their abilities to design integrated circuits. One of them, the Boeing Company, called in an outside expert, who recommended that the company tap the resources of the Computer Science Department of the University of Washington. The University, he told them, was the logical focal point for such a project.

Discussions began among five companies—Boeing, Honeywell, Tektronix, John Fluke Manufacturing Company, and Microtel Pacific Research Limited of Canada—and the Computer Science people, of how such an arrangement would look. Each of the five companies had its own reasons for being interested in circuit chips. They are all high technology companies that use integrated circuits in their products, although no firm is dedicated exclusively to the manufacture and design of chips. The field changes so quickly that they could only make the best products by maintaining a position on the forefront of research—a position more easily achievable through regular contact with a major research university.

Each company, under the proposed agreement would contribute $65,000, which would be used toward the purchase of a computer for the project and its operation. Each company would designate one employee as a project liaison person, who would be assigned full-time to work with the other members of the team. The project would take place at a central location on campus. There, company people would meet with one another and with faculty members. They would carry ideas back to the company, when a proprietary setting was appropriate. Other ideas would be pursued on campus, as part of the project.

Decisions concerning research policies would be made by a governing board. Member companies could obtain licenses, free of charge, for products developed under the agreement. In addition, the University would be able to license products to non-participants through the Washington Research Foundation or other such organizations.

A very key element in all of this was that initially, a major part of the project's finances would be underwritten by a research award from federal funds (Defense Advanced Research Projects Agency), DARPA is interested in this work because of its possible application to a variety of problems in industry and, of course, more particularly in defense work.

The actual negotiation of what became known as the VLSI Consortium Agreement—VLSI stands for very large scale integration—was a long process. Although we and the companies were in substantial agreement about the overall aims of our cooperation, the details were hard to put in writing. For instance, the companies were concerned that the agreement not appear to be a partnership—otherwise, it would run afoul of antitrust laws. There was also the issue of indemnification, so that no participant was liable if a circuit developed in the project damaged another participant's computer or test equipment. Trying to consider all eventualities made the document take on a formidable aspect, full of necessary legalisms that we hoped did not detract from our basic aims.

In looking at our Department of Computer Science, we felt confident that the VLSI Consortium would merely be part of the research that was performed there and would by no means dictate the projects on which the Department would concentrate. Our Department is fairly large and diverse. It has a numbr of federal grants, including a very large one from the National Science Foundation. Had circumstances been different—for instance, if the Department were smaller and had fewer other research dollars—the issue of concentrating our effort to such a degree might have been more worrisome.

Since the agreement was signed just a little more than a year ago, we do not have enough of a track record to judge fully the success of our negotiations. The project itself began only last summer, when the contract was received from DARPA. One problem we knew of in advance, however, is one that cannot be negotiated away. It stems from the different time perspective of universities and private industries.

Generally, industries are looking for results on this year's or next year's balance sheets. They want to spend money on research that has an immediate payoff. There is reluctance when we have asked industrial representatives if they are willing to support basic research. Our faculty members, in contrast, are more interested in fundamental questions—in finding out why something happens—even if, for many questions, that means the answers may be years away.

Right now, the VLSI Consortium appears to be able to provide enough of what both sides want. The agreement separates the project into two divisions, a research division and a systems evaluation division. The companies can decide to have their liaison person involved in either area, depending on current corporate priorities. One year, they may want to concentrate on basic research. In another, they may be more concerned with systems evaluation, which is more immediately related to product development. But our agreement ensures that both divisions must be functional.

It is possible that circumstances will change, and that at some point the technology of circuit design may become so mundane that it is no longer of academic interest. It is also possible that the developments will become so lucrative that the University will have trouble holding on to the project, and that we may drain faculty members and graduate students from the Computer Science Department into a "spinoff" company.

Several spinoff companies already have started from University-related research, and they all maintain fairly close ties with the campus. One such company, Genetic Systems Corporation, has specialized in using monoclonal antibodies for medical diagnosis and disease therapy. The company has an active research program and collaborates with faculty in a number of departments. It is an example of the kind of rewarding relationship that can exist between a small, high technology firm and a university.

Risks are present. But in at least one sense, we have learned that now may be the ideal time for more cooperative ventures between university and industry. Discoveries in several fields—computer science and biotechnology are the most notable—have decreased the distance between basic and applied research. Where we used to speak in terms of many years between laboratory development and industrial licensing, we now may be talking in terms of only a few years or even months. In a way, the more recognizable the tie between industrial products and what we have always done on campus—basic research—the easier it should be to develop equitable and effective technology transfer arrangements.

I have probably devoted more attention to describing the VLSI developments at the University of Washington than one might expect, considering the overall scope of these hearings. At the same time, the several fruitful programs of university-industry collaboration that are in place or are being developed should have an important impact on the economic well-being of our region. Further, they depend heavily on federal support of basic research and graduate education.

CONCLUSION

In conclusion, Mr. Chairman, we are hearing much these days about the potential to meet the nation's needs for research and highly trained people by forging closer ties between universities and industry. As I have tried to illustrate, it is true that there are important opportunities to strengthen those ties in ways that will result in greater investments by industry in university research and education programs. After looking at the current scene with some care, however, I can only conclude that the long-range potential for major financial support is quite limited.

While much attention is being given to a relatively small number of potentially significant and highly publicized cooperative arrangements, these are most important in encouraging improved technology transfer. For most disciplines, sustained national investment in basic science, funded through the agencies of our federal government, must continue to be the primary, even sole, source of research support.

The fiscal year 1984 request of the National Science Foundation sustains and strengthens the nation's commitment to university research programs. We ask the Committee to support fully the Foundation's requests and to give serious consideration to building upon them across all agencies along the lines suggested here.

I appreciate the opportunity to appear before the Committee today. I will be pleased to answer any questions you may have.

Senator GORTON. Thank you both very much.

I am sure that you know that we on this subcommittee, Senator Heflin and myself and all the other members, are as pleased as you are to see that the administration has recognized the importance of NSF and has proposed for it a relatively large increase for fiscal year 1984 in comparison with literally hundreds of other agencies.

Each of you in his written testimony, however, has commented about questions relating to the stability of future funding for NSF. And I wonder if you could expand on that issue a little.

First, as it affects your view of what's likely to happen if we continue the same kind of policies and approach toward NSF in the next couple of years; and second, whether you see a source for stable funding for basic research which we could look to for potential incorporation into the law. I would like to have each of you comment on that, if you will.

Dr. PRESS. The nature of the scientific enterprise in terms of definiting a research project, and gathering technicians, graduate students and staff to work on it is an activity that involves a commitment of perhaps 5 to 8 years in a given research area. One has to accumulate instrumentation, build space and so on. To undertake that kind of activity requires a certain degree of commitment because careers are being invested, graduate theses are contingent upon its completion, and so forth.

One cannot do that well and one cannot do it with maximum productivity in an atmosphere of uncertainty. Many projects that are very worthy and that have great possible returns are not even started in such an environment of uncertainty. So stability and predictability in science are particularly sensitive and important factors.

There are a number of ways to provide this stability. Parenthetically, I should add that scientists do not have an unreasonable call on the Federal budget. However, within existing funding levels, for example, if appropriations can be made over several years at a time, if the granting agencies—some do and others do not—can make commitments to provide grants for 3 to 5 years, subject to the appropriation process, these would help a great deal.

Also, I do agree with Dr. Keyworth that basic research is only 14 percent of the Federal R&D budget, and the D part of the budget is an uncertain area for the Government, for the Federal Government, whereas the basic research part is, for good reasons, generally agreed to be an essential task of the Federal Government.

I think of the D part of the Federal R&D budget, which amounts to some $30 billion, can be scrubbed down and analyzed and subjected to the kind of review that identifies worthy projects and projects which are not perhaps that worthy. From this exercise additional funds might be found by transferring from D to R that would be sufficient to support this stability, this need for stability and continuity in the basic research category.

We must understand that intrinsic to the nature of science is a built-in inflationary characteristic, independent of economic inflation. The more that nature's secrets are unraveled, the more difficult it is to discover the remaining ones. As a result, future discoveries become more expensive as instrumentation becomes more complicated, technical skills more demanding, and demands for computer uses expand.

Dr. **Richardson**. I think Dr. Press said it well indeed. One thing that he said at the outset seems particularly important: careers are invested in it. That is a very crucial observation. The notion of attracting bright, young minds to basic science—as opposed to a number of other things that bright, young minds might do, including development work or work in various careers—industry—is a very crucial matter for the future of the Nation.

If we have a stable environment in which we can assure science careers that are attractive and in which there can be an orderly career development, then it seems to me we will greatly strengthen the Nation's capacity to support what is after all the major factor contributing to productivity increases in the country.

Senator **Gorton**. You have both been extremely eloquent on the need for stability. But I am not sure you have told us how we can provide it. Obviously, we work on an annual authorization cycle and an annual appropriations cycle. Unless this somehow or other becomes an area in which there is an earmarked source of revenue, it is very, very difficult for anyone to be able to say where we are going to be in 5 years or 7 years or even 2 or 3.

So I suppose the heart of the problem is that the research community, it seems to me, needs to help us with some constructive ideas as to how to create this degree of stability, the need for which we all recognize.

Dr. **Richardson**. It does seem to me, Mr. Chairman, that the fact that we are appearing today before a subcommittee of the Commerce Committee is very consequential in thinking of that issue. More and more the link between basic research and its fruits in terms of product development and productivity and indeed even in cost containment, for example, within health care—as one thinks of solutions to problems that are whole solutions rather than halfway solutions—all suggest that the Nation's commerce is dependent on basic research. Therefore, one ought to be able to build such a base of predictable earmarked funding.

Senator **Gorton**. Dr. Press, could you discuss how NSF sets priorities for its programs, and especially what the role of the scientific community itself is in establishing these priorities, including the National Academy?

Dr. **Press**. The NSF is a unique agency within the Government in that it has a Presidentially appointed National Science Board drawn from the university community, and the industrial community, the educational community. That board has unusual authorities for a Government agency—it is a part-time board—namely, in setting priorities and evaluating budgetary proposals.

So through the National Science Board, there is in a sense a network to the outside scientific community, a means of obtaining advice, reviewing priorities, discussing large science versus small science, and evaluating the relative importance of opportunities in one field as compared to another. That practice works well, and we should encourage it.

In addition, the Science Foundation has established a number of advisory committees for such major disciplines as physics, chemistry, oceanography, and astronomy. They use those committees well.

So I believe the National Science Foundation, through the unique historical development that led to what I just described, provides a reasonably good process of communication and outreach for seeking advice across the country. And the NSF, to its credit, tries to do this with good geographic distribution as well as adequate representation of the research fields and the educational community. I believe the process has worked well.

As in all areas, it depends on the case that can be made for a given opportunity in oceanography versus astronomy versus physics versus engineering, whatever. In times past there have been mistakes, I must admit, where certain important scientific fields, were underfunded for as much as a decade. But these deficiencies soon became recognized and adjustments were made to compensate, as I think as the recent National Science Foundation budget indicates.

If I may say something very briefly about your previous question, I agree with you that the scientific community has to make a case for the support of science to the public and through the public to Congress. And it is not a difficult case to make when one thinks of the contributions that have come from the university research community; the very basis of the stored program computer which is so important to our economy today; the whole area of molecular biology, antibiotics, solid state physics which led to transistors and integrated circuits—all of these were research contributions by universities over the decades. And this is what we have to keep saying to the public and explaining, why science is worthy as a public investment.

Senator GORTON. Dr. Richardson, in your written testimony you emphasize the need to increase the number of scholarships. By the same token, it looks as though the budget increases the average dollar amount rather than the number. Can you comment on that difference and why you differ from that?

Dr. RICHARDSON. In my written testimony I called attention to the numbers and the levels, of stipends, as well. As you know, the levels have dropped off alarmingly over the last 15 years, I think reflecting again just a period of neglect.

When one considers the country as a whole and the various branches of science, it is surprising that there were only 500 new starts for NSF, or in the case of last year's new Defense Department program for engineering, I believe there were 66 fellowships awarded. These are very, very small numbers considering the talent available and the needs for graduate students and young scientists.

But the other point is the level of those stipends. At the University of Washington, for example, we currently have active 33 NSF fellows. Their stipends average $6,900. When one considers the competition from industry for the brightest minds, something like the DOD level of $12,000, it seems to me, is much more realistic. So the levels need to be increased in order to attract people into university-based science. But also, as I pointed out in my testimony, the numbers need to be increased.

Senator GORTON. On a specific subject, you emphasized the need to improve instrumentation. As you know, this budget does take a real step forward in that respect. Will the other instrumentation provisions in the NSF and other agency budgets, including Defense, have a major impact on university research?

Dr. RICHARDSON. Certainly the increases will have an important impact in the ability of research-oriented departments to carry out their work in a way that is far more satisfactory.

Although I do not have all of the increases accumulated, from my understanding, I do not think that the levels that we are talking about are sufficient to the problem. Just to cite again a local example, the Department of Defense program that was started last year, which was $30 million a year for 5 years for university instrumentation, elicited at the University of Washington proposals carefully screened at the departmental level and sent forward to my office that added up, not counting a State match, to $12 million.

Well, our share of the DOD $30 million would be about $600,000 or $700,000, so we are talking about an order of magnitude difference between the program funding level and the rather carefully documented need. The ratio of need to funding was 15 or 20 to 1. So while it is a great help to have the emphasis on instrumentation and the increases made, I still think that we are talking about a major recapitalization rather than incremental support levels.

Senator GORTON. You talk about $2 billion over 5 years as an appropriate commitment by the Federal Government in that respect. What proportion of this rebuilding cost should come from outside of the Federal Government—from the university itself, from State governments, and for that matter, from the private sector?

Dr. RICHARDSON. I would not venture a guess as to what the appropriate portion would be, but I would certainly feel that it would be appropriate to expect local sources to provide funding for instrumentation. In our State and, I am sure, in many others, there seems to be a much greater sense of responsibility for instrumentation for teaching programs than for the conduct of basic research. Here I am thinking largely in terms of basic science per se as it contributes to the Nation of welfare, as opposed to science awareness or general education or undergraduate education, as important as those are.

So at the State level, we have continued to make major budget requests to our own legislature for equipment. Indeed in the Governor's budget there is included instrumentation funding oriented largely toward instructional needs. And similarly, private industry has been very helpful to us, and influenced by the changes in the Tax Code in 1981, in providing to us instrumentation itself.

But I still would suggest that the Federal role is the major one.

Senator GORTON. Senator Heflin.

Senator HEFLIN. Dr. Press, you and Dr. Richardson both made excellent statements and I congratulate you upon your wisdom and your insight into these issues. We certainly welcome thoughtful input on scientific issues.

Dr. Press, one area you did not discuss a great deal is the Federal responsibility for science, mathematics, and engineering education. I assume you consider this a high-priority area. Would you elaborate on what your thoughts are pertaining to the issue today, which is a top issue, that is, of science, math, and engineering education?

Dr. **Press**. I appreciate your raising that point, Senator Heflin. I think it is a crucial issue and one can respond to your question in many different ways.

Perhaps you may have seen the New York Stock Exchange study of Japan's productivity, where in the view of the economists of the New York Stock Exchange, the most important influence on productivity was the high school education received by Japanese students; the quality of that education.

The deterioration of this Nation's precollege science and math education over the last 10 years can't be described any less than a national disgrace, and it will have lasting effects in the years ahead in terms of inadequately skilled workers and an uneducated populace less able to understand the issues of the day controlling their lives.

I am delighted to see that the country is responding to this crisis. There are a large number of bills in Congress addressing this issue right now. The administration also has come forward with a proposal which addresses the issue. I don't believe it is sufficiently funded, and I heartily endorse the House bill that was approved just last week addressing the same issue with a larger level of funding.

I think we have to recognize that education in this country is a local responsibility and most of the funds will come locally. However, the Federal Government traditionally has played an important role in setting the pace, providing incentives, and setting up model programs such as summer institutes for teachers and loans for teachers who will commit themselves to science and math careers in our high schools.

The Federal role, as I said, is just one aspect of the problem. I believe the country has to recognize the importance of our school teachers and reward them more handsomely than they have been in the past. Today their careers are not very attractive ones in terms of salary and status, and that is unfortunate.

When I was a young student, the school teacher was the most distinguished person in the community. That is the way it is in Germany and that is the way it is in Japan, but somehow over the years we have turned away from that recognition, and my view is that we have to change that trend.

The Federal Government can set the pace in these directions in a way that the House bill does indicate.

Senator **Heflin**. The administration's budget calls for a block grant approach toward some of these issues. Do you see a Federal role? There are arguments that have been propounded, like new, innovative teaching approaches, the issue of supplying, in effect, computer literacy by the use of having an adequate number of small computers in most of the high schools, and the various other methods involved in this in which you could see a disparity of approach under a block grant approach and whether or not there is a role the Federal Government ought to play in this.

Would you give us your thoughts relative to the role that the Federal Government ought to play as opposed to a block grant or a block grant as a supplement, or any thoughts that you have on this matter?

Dr. PRESS. Well, I would like to think it through more carefully before I respond to the issue of block grants versus other approaches in terms of the Federal role. I am concerned, however, with the administration's proposal about how those block grants would be used.

One aspect of the administration's proposal is to provide 1-year training courses to convert teachers in other disciplines, unemployed teachers, to math and science teachers. That simply cannot happen. It cannot be done well. To train a mathematics or a physics or a chemistry teacher requires a sequence of courses and training that will take more than 1 year.

I would prefer that the proposal be in the direction of providing loans that might be forgiven for those who remain in the school systems. In this way a proper education in math and physics and chemistry can be provided over a required period of several years. I also would like to see the standards raised significantly for our schools of education.

The requirements for graduation in terms of knowledge of math and physics and other sciences should be increased by our high schools. I would like to see the admissions requirements for universities go up as well. All of these objectives are important parts of an overall approach to the problem of precollege science and math education.

Past experience indicates that a strong Federal support role has worked well in the area of curriculum development for teaching science and mathematics. Perhaps, as an example, the Federal Government can play an innovative role in promoting the uses of computer programs for educational purposes in these disciplines.

Summer institutes to provide disciplinary enrichment for school teachers have been very successful in the past. Also, summer courses for unusually talented students have contributed significantly to the training of our new generation of scientists. There are a number of different ways of approaching this that can be explored.

The main thing is to start a new partnership between the Government and the local school districts. Industry also has a role to play in this cooperative effort and industry is now playing that role. Then as a nation we can address this important problem.

Senator HEFLIN. Dr. Richardson, would you care to comment on this issue?

Dr. RICHARDSON. I would have nothing to add to what Dr. Press has said, Senator.

Senator HEFLIN. Some of the people looking to the future job market are saying that 40 years ago the job market was manual labor; today the job market is skilled labor; that the job market of the future will require an analytical approach toward almost any and all issues; and in order to train for the job markets of the future, it is necessary that education at the high school level go into the fundamentals of analysis, go into the fundamentals of how you train a future person to have an analytical approach.

All of these issues, of course, are important, and as we do it, of course, there are subjects that do relate to the analytical process, not only just from science, but other methods.

Another idea that has been expressed as we move toward more computer literacy, as we move toward more high technology is that we are going to find that it is still basic subjects. That we are going to need a new basic emphasis. As computers spit out the written word more and more of the ability to express, the ability to communicate through the written word is going to be more and more important, and that we shouldn't lose sight of the basic subjects in education.

I just wondered if any of you have any thoughts as to the training of future occupants of jobs as you foresee the job market in the future. I don't anticipate that we are going to have everybody in high technology, but we are going to have a sizable portion of our work force in high technology 20 years from now. I think that the demands in other types of jobs are going to be changed.

Do you see a relationship at the educational level in science-related matters and in basic subjects that we ought to be approaching in giving thought and study and planning for the future?

Dr. RICHARDSON. I think in our own setting, Senator, there is very little question that all that you describe is, in fact, abrew, and indeed several specific things are notable. One is that we are seeing a closer relationship between high schools and colleges and universities in planning a more orderly and balanced transition. We are seeing longer range planning and attention to balance within universities between areas in the humanities and science and technology.

There is, of course, certain fear on the part of those whose specific interests are not particularly science and technology that our universities and colleges are going to be turned all to institutes of technology. If one actually looks at the directions we are moving, my own impression is that we are shoring up what has been a neglected area in recent years and the one that clearly is going to be crucial to our national interests in the coming decades.

But at the same time we are, I think, attending to the needs in the humanities and other areas. I don't mean only with financial support, but in terms of discussions of how those areas may relate to new technology, and I would hope that that combination of an orderly progression from secondary school to college or university, and a careful balance at the university level would lead us into the appropriate mix for the labor market, at least for those coming out of postsecondary education.

Senator GORTON. Thank you both very much for your help and for your enlightening testimony.

We will now move to our second panel, consisting of Dr. Branscomb, Dr. Kennedy, Dr. Penzias, and Dr. Bartlett.

Senator, do you want to introduce Dr. Bartlett to us?

Senator HEFLIN. Yes, I would very much like to introduce Dr. Bartlett. Dr. Bartlett is the chancellor of the University of Alabama System. He took over last year and already has made a name for himself. He had a series of articles that appeared in an Alabama newspaper on research and its importance in the future.

Before coming to the University of Alabama, he was president of the Association of American Universities headquartered here in Washington, and in his capacity organized and directed several Federal relations programs on behalf of research institutions.

I wish I could say that he was originally from the South, but he happens to be from that section of the country close to the State of Washington, the State of Oregon. So we are delighted that he has shown the wisdom to come to Alabama and adopt it as his State.

Senator **Gorton**. We thank you.

Now that we have seated all of you here, and each of you is welcome, I note that we are beginning a rollcall which Senator Heflin and I will have to attend. Rather than to break up your testimony, we will give you a break before you start and come back as promptly as we can to hear from you.

We will recess.

[Recess.]

Senator **Trible** [presiding]. Gentlemen, let me welcome you. I am Senator Paul Trible of Virginia. On behalf of my colleague, Senator Gorton, let me again express his regret that he cannot be here personally, but it is necessary for him to attend a Budget Committee meeting at this time. The Senate is endeavoring to mark up a budget for the next fiscal year, no small endeavor, and it does require his presence.

I would ask that each of the distinguished members of the subcommittee would introduce himself, and then if each of you would give us the benefit of your testimony, either in whole or in part or a summary, we would be most pleased to hear from you today.

We will make your full statement a part of the record, so if you choose to summarize your statement, that will be just fine.

STATEMENTS OF DR. LEWIS N. BRANSCOMB, VICE PRESIDENT AND CHIEF SCIENTIST, INTERNATIONAL BUSINESS MACHINES; DR. DONALD KENNEDY, PRESIDENT, STANFORD UNIVERSITY; DR. ARNO PENZIAS, VICE PRESIDENT OF RESEARCH, BELL LABORATORIES; AND DR. THOMAS BARTLETT, CHANCELLOR, UNIVERSITY OF ALABAMA SYSTEM

Dr. **Branscomb**. Thank you very much, Senator Trible. I am Lewis Branscomb, vice president and chief scientist of the International Business Machines Corp.

Would you like each of us to introduce ourselves at the outset?

Senator **Trible**. Doctor, just begin, and each of our witnesses can do so.

Dr. **Branscomb**. I have a very brief biography that I will give to the reporter for the record.

I am also part-time Chairman of the National Science Board, which, as you know, is the governing, policysetting body of the National Science Foundation, but I appear here today in my capacity as an industrial scientist, not representing the Board.

I am very pleased that Dr. Mary Good, our distinguished Vice Chairman, did appear before this committee last week and did, I believe, describe the Board's involvement in preparation of this budget.

Let me say at the outset that my company, which is in the middle of what are generally considered to be the high technology industries that are emerging, is very proud of the record of our industry. Our products are increasing their capability by 25 percent every year without an increase in cost, and this results in an industry growing at 15 percent a year.

It is important to appreciate that this industry is a productivity driver. The computer is the productivity engine of our time, and the employment growth in the industry is significant. It is not as great as the total growth of the industry in dollars because its productivity is going up so rapidly, but what we need to focus on is the capability of high technology industry, and here I include the new biomedical industries and others, not just information industries, computers, and communications.

The issue is the power of those high technology industries to provide productivity growth to the entire economy of the country. If our industry adds 50,000 people a year, as it has been doing recently, that is a contribution to the unemployment problem; but if our industry can somehow or other increase the productivity of the entire economy by 1 percent, then we have put 8 million people to work if jobs are reflected directly against that productivity.

I would like today to try to impress the committee with our concern for the health of American science, research, and education and the National Science Foundation by indicating to you the way in which the technical skills available to us; the knowledge base that we depend upon; the math skills and computer literacy of our customers, employees and the public influence; the dynamic growth of that industry, and what we are doing about it.

I will cover that very quickly because it is covered in my prepared testimony and I would like to get to what I think, then the Government should do about it.

There are five questions that concern me as chief scientist of IBM. First, will we be able to recruit the highly skilled professional men and women trained in specific fields that are critical to our progress, such as computer science and engineering, materials science, polymer chemistry, et cetera?

Second, will the universities and other nonproprietary laboratories be able to make the novel contributions in these critical fields that permit our laboratories and those of other companies in our industry to sustain the innovation rates that are necessary to remain internationally competitive?

Third, will our engineering schools have the capability not only to train but to motivate young engineers for emerging new careers in the private sector where production technology now poses as sophisticated a technical challenge as R&D has in the past?

Fourth, will the strength, vitality, and sophistication of the academic, scientific, and engineering community across all disciplines provide us not only with the basic knowledge but the standard for creative achievement and intellectual discipline needed to stimulate the entire technical enterprise, basic and applied, to high levels of achievement?

Finally, will our industry growth and our opportunity to contribute productivity to other sectors be frustrated ultimately by deficiencies in the education of young people in elementary and secondary school, or for that matter, the adult public's lack of preparation for the emerging tools of an information-rich economy?

I think Senator Heflin's comment earlier today was very perceptive when he noted that information technologies will produce a lot more information in text form, much of which was oral before.

People have noted that while the high technology industries may not be a great source of new employment in terms of millions, and in fact the projections show we will need a half-million truckdrivers added to the work force in the next period of years, those truckdrivers are going to be dispatched in the future by a computer generated dispatch sheet.

I am sure they will be interacting with information systems in every aspect of their work, and they will have to be able to read and understand and act intelligently on the basis of these instructions.

Now, for many years we have been active in philanthropy within educational institutions, and that has certainly continued. Last year we donated $21 million to educational institutions, primarily for human resource development and to encourage innovative accomplishments in science, engineering, economics, and management; but our most important relationships with the universities now derive through collaborative activities in specific areas.

That is in part, for example, because I believe, as I think Senator Gorton noted in his speech January 22, which I just read in the Congressional Record this morning, that the competition we are facing from the Japanese is to a degree in science and, to a more important degree, in innovation, but it is overwhelmingly competition in low cost, high quality manufacturing.

The Japanese take manufacturing technology seriously, and their young engineers look forward to careers in factories. In the United States the factory is no longer a respected institution. It is in Japan, and in the United States that needs to be reversed.

Last summer IBM announced its intention to donate $50 million in equipment and money to U.S. schools of engineering who will find their own path for responding to this challenge. We thought we might have trouble finding a dozen or two engineering schools interested in manufacturing systems engineering, but 162 engineering schools responded, and we have gotten many letters even from those we had to turn down for our small planning grants saying we had done them a favor because they had been able to get the message to people they had been trying to reach for years that they really wanted to work in this area and it ought to be an area that high technology skills will be drawn to.

That is the productivity opportunity. It is not the only thing we need to do, but it is important.

We also found universities are imaginative users of our technology and in many cases may be the precursors of tomorrow's commercial systems. I think a fine example of that is what almost every major university is now trying to do in the field of distributed computer communications. We have a large project with Carnegie-Mellon University in that area aimed at equipping every student, professor and staff member with access to a powerful work station in a network in the next few years.

We also find that universities are a powerful source for demonstrating the scientific feasibility of very advanced instruments and other devices. We have a large project at the MIT National Magnet

Lab, for example, to build several superconducting nuclear magnetic resonance imaging systems, which I think can be the medical diagnostic tool of the future, eliminating X-ray hazard and greatly expanding the power of diagnosis.

But these are large projects and they are the ones that usually make the newspapers. In point of fact, the greatest and most important activities we have are not these large projects but are many small projects between our engineers and scientists and colleagues in universities who want to do something together. At last count, we had worldwide over 460 such projects in 150 universities, the vast majority of them in the United States.

I am very concerned about the perverse impact of the laws of supply and demand economics when applied to critical human resources from our universities. In the field of computer science, it is obviously critical to us. The number of Ph. D.'s who are finishing their work in computer science has been on the decline since 1979.

How can that be when salaries have reached the sky? The demand is tremendous. Conventional economic theory would suggest that the great demand for such people would have caused the numbers to increase dramatically. The problem, of course, is that attractive positions in the commercial world at the master's degree level are causing our young people to leave their graduate work before completion of the Ph. D. degree.

The end result of this phenomenon is depletion of faculties, and that, of course, increases the teaching load on the remaining faculty, reducing the attractiveness of a faculty career compared to industry and exacerbating the problem all the more.

Now, because of our concern with this problem, we are planning to expand our graduate fellowship program that we fund at universities to 200 fellowships. We are providing departmental grants to be used flexibly by department chairmen for their young faculty, and we are putting $1.5 million a year into small grants for that purpose.

Finally, let me say that the capability of our colleges and universities to invigorate the scientific and engineering base for America's economic competitiveness rests fundamentally on the K through 12 school system. Deficiencies in the math and science programs are all well documented. I will not try to spell that out again, but those deficiencies could frustrate all the other efforts to strengthen American science and engineering, and they can also frustrate the responsiveness of all sectors of our economy to take advantage of the productivity tools that are coming.

So this is an area in which we have faculty loan programs to secondary schools. We are working with local communities to train teachers to respond to the tidal wave of student interest in computing. For example, in Rochester, Minn., working with a local junior high and high schools, we will have 6,000 students going through a program of training by their teachers whom we have helped during the summer.

Now, I hope this brief recitation will convey some of the sense of urgency we feel about addressing these issues. The universities have been initiators of prospects for whole new industries. Microbiology is today's best example. It came from the universities with Federal funding for basic science.

In these kinds of situations the Government, in my view, ought to give serious attention not only to strengthening the basic research, as Dr. Press recommended earlier, in this field in the plant and life sciences, but now to look at the advanced technologies that will be required to make the scientific breakthroughs pay off in jobs and wealth for Americans.

I worry, for example, in reading reports that permutation technology is something the Japanese have a great deal of experience with, if our country does not. If that is critical to exploiting these new inventions, then our science, once again, will play to their advantage.

In the computer industry, the history is opposite to that. The first Ph. D. in computer science was awarded in about 1965. The industry was already quite robust and growing rapidly. The consequence is that we have tens of thousands of engineers in our industry trained prior to the time when the universities put together what is now the right education to work in this kind of field. And that capability can transform our industry. So even though the industry moved faster than the universities did in this case, we are evermore dependent on them for the next echelon growth.

Now, having emphasized as much as I have what industry can do to help because I think it conveys our sense of concern and urgency, let me hasten to call your attention to the data in the National Science Board's recent report to the Congress which notes that industrial support for academic R&D in the United States is larger than most people thought it was, and it is growing, but it is less than 7 or 8 percent of the total.

More importantly, total industrial philanthropy to higher education for all purposes is less than 3 percent of those universities' operating costs. So an important role for Federal funding of our universities is to permit the universities to take action when, through their own insight or through collaboration with industry, they find that they should build new programs in an area that they think is appropriate to their mission, to their skills and desires, and to the needs of the country.

The manufacturing systems engineering example I mentioned earlier is a splendid example. We can make $50 million available, but we need something like title II of H.R. 1310 or something like Senator Gorton's proposal which I have not yet seen, but I have read about in his speech, to permit the universities to pick up that ball on their own and carry it where they think it ought to be taken.

Just such a program was recommended to the President by his National Productivity Advisory Committee, of which I am a member, last December 14. That recommendation is a discussion of the problem as well as a recommendation for a program of matching funds to universities in the manufacturing technology area. And I would be happy to make that short four-page statement available to the committee if you would like to have it.

Senator **Trible**. Please do so, thank you.

Dr. **Branscomb**. I would like to make a very brief comment about a few other items. First, the issue of engineering education. I think there has been a great deal of discussion of the need to strengthen the engineering program in this country. The point I would like to emphasize is that engineers do basic research right at the cutting edge. They need basic research funds, just as physicists and chemists do. But while funding basic research with its attendant research assistantships, its facilities, and equipment is an excellent way, a time-proven way to strengthen education at the graduate level in physics and chemistry and mathematics, it is an insufficient—necessary but insufficient way to strengthen engineering.

Engineering being a clinical practice of technical fields, if you like, deals with very complex and difficult problems, and they have many educational issues that need education money to solve. And, therefore, I think the strategic or philosophical basis for Federal support for engineering needs to have a slightly different character than that which we are accustomed to for science.

I will just echo what others have said about the $2 billion equipment shortfall. I can attest to the fact that our university scientists are not working at the optimum productivity because of the imbalance in their equipment capability, and that must be addressed.

Third, I would like to just comment on the question of whether there is a shortage of engineers in our economy. And I would urge you to pay very little attention to manpower estimates or economic analyses that purport to say the Japanese have that many engineers, we have this many; we will need so many in the future.

The truth is the Japanese use a lot more engineers than we do. They use them for a broad variety of tasks, many of which we would consider beneath the level of professional engineers, when the people are young. But the Japanese bring superior skill and education to those tasks, and the benefits to their employers are quite evident. So I believe that employers in this country would use a lot more engineers if they had the management skill to use them properly, and if the engineers were trained and motivated to address the real problems of a much broader spectrum of employers than the great research corporations.

It is necessary here to observe that much of the relationship between industry and universities does involve the big high technology companies, and we should all be working on getting the innovative, middle-sized companies too small to do research assistance more involved.

My final comment is simply to observe that we have been through a couple of years of debate on the Federal role in education, science engineering, and industrial development. Having listened to the President's state of the Union message and studied this 1984 R&D budget and education budget, I believe all sides in the public debate now share a common aim and a common view on the fact that our economic wellbeing does rest upon science, education, and research. We may differ on the methods, but we are in agreement on the objectives, and I am, therefore, optimistic that a consensus is building for both Federal and private actions that will make us the strong country we know we ought to be.

[The statement follows:]

STATEMENT OF DR. LEWIS N. BRANSCOMB, VICE PRESIDENT AND CHIEF SCIENTIST, IBM CORP.

My name is Lewis M. Branscomb. I am Vice President and Chief Scientist of the IBM Corporation and appear before you today in that capacity. I also serve part time as the Chairman of the National Science Board, which has policy responsibility for the National Science Foundation whose 1984 fiscal year authorization is the current concern of this important Committee.

I commend the Committee's interest in the health of America's research and engineering enterprise, particularly as it relates to the need for rebuilding our economy. This morning I want to address the questions that must be faced by the Congress from the perspective of the IBM Corporation. Technological competitiveness is the key to the success, indeed the survival, of our company. We are very proud of our record, in an industry which delivers each year 25 percent more capability in its products for no increase in cost year in and year out. This has resulted in a growth rate for the industry averaging around 15 percent per annum, which constitutes an important stimulus to the economy as a whole. Most important, the products of the information industry contribute directly to the productivity of all sectors of the economy that make productive use of them. The computer is the productivity engine of our time. I often refer to it as a motor for the mind.

Ours is a highly-competitive business worldwide. To grow one must be, on average, the low-cost producer. Technology close to the cutting edge of science, skills close to the cutting edge of education and management with an eye on the future are the keys to producing sophisticated products at the lowest possible cost.

We are, therefore, dependent for our success on the technical skill levels available to us for new hires, the knowledge base in appropriate fields of science and engineering on which our technical work must draw, and the math skills and computer literacy of our customers' employees, and the general public. For this reason we dedicate substantial funds, management effort, and the time and experience of our scientists and engineers to helping universities and schools remedy critical deficiencies in this external environment where they might influence our future.

I believe I can best express our concern for these issues if I describe some of these IBM efforts to assist our universities and schools. I will then turn to what I believe is the appropriate challenge for the Federal Government, in partnership with industry and universities, to set our country on a sound course for the future.

These five questions are of primary concern to me as IBM Chief Scientist:

(1) Will we be able to recruit a sufficient number of highly skilled professional men and women trained in fields critical to our progress (such as computer science and engineering, materials science, polymer chemistry, etc.)?

(2) Will the universities, and other non-proprietary laboratories, be able to make sufficiently novel contributions in these critical fields to permit our company laboratories to sustain the innovation rates necessary to remain competitive?

(3) Will America's engineering schools have the capability to not only train, but motivate young engineers for emerging new careers in the private sector, where production now poses as sophisticated technology challenges as research and development have in the past?

(4) Will the strength, vitality and sophistication of the academic scientific and engineering community, across all disciplines, provide us with not only the knowledge, but the standard for creative achievement and intellectual discipline needed to stimulate the entire technical enterprise, basic and applied, to high levels of achievement?

(5) Will the growth of our industry, and its opportunity to contribute to the productivity of all other sectors of our economy, he impeded by deficiencies in our young people's educational experience in elementary and secondary school or by the adult public's lack of preparation for the emerging tools of an information-rich economy?

For many years our company has contributed philanthropically to educational institutions because it was in our business interest and the public interest. Over the years our dependency on these institutions has substantially grown. Last year we contributed $21 million to educational institutions primarily for human resource development and to encourage innovative accomplishments in science, engineering, economics and management.

Our most important relationships with universities, however, arise through collaborative activities on specific topics.

For example, because of our concern that America's lead in science and product innovation is not matched by a comparable lead in low cost, high-quality manufacturing, we announced last summer our plan to donate $50 million in computer-aided design equipment and cash for curriculum development in U.S. schools of engineering. One hundred sixty-two engineering schools responded; a strong indication that the relatively weak position our institutions enjoy in this field, compared to Japan, has its origin not in the desires of the leaders of our engineering schools, but in the patterns of prior support and the inelasticity of our educational institutions to rapid change.

The universities also represent important source of innovative ideas for our industry, and in some circumstances their own requirements set a prototypical example for what we believe will be commercial systems of the future. For example, the joint development project between Carnegie-Mellon University and IBM, aimed at the development of a unique distributed computer system with thousands of powerful workstations in a communications network, could, we believe, be the harbinger of future directions for the industry.

There are other areas in which universities are breaking new ground with great prospects for the long-term future. For example, we are supporting the development at MIT of several prototype superconducting, nuclear magnetic resonance imaging systems, which could be the medical diagnostic tool of the future, eliminating x-ray hazard and greatly expanding the power of diagnostic capability.

There are other fields, such as magnetic science and technology, which have gone largely neglected in the universities, yet represent, in information storage product, as large a source of employment and revenue for the information industry as do all of the silicon chips we hear so much about. In this case, there are active discussions among a number of companies including IBM of the feasibility of helping one or more universities establish centers of expertise in this field.

The most important research relationships we have with universities, however, are not the large, highly-structured projects that make the front pages. They are a very large number of collaborative relationships between small numbers of individuals in our laboratories and in university departments who joined together because of their common interest in a significant, technical problem. Collaborative research activities of this kind have grown dramatically over the past two years. At last count, IBM had more then 400 such projects with 100 U.S. universities.

In the same vein, we have participated in the semiconductor research consortium through which university investigators are funded to do advanced basic research in microelectronics.

We are very concerned about the perverse impact of the laws of supply and demand economics when applied to critical human resources from our universities. The field of computer science is critical to us. The number of Ph. D.'s completing their work in computer science has been on the decline since 1979. Conventional economic theory would suggest the great demand for such people should have caused the numbers to increase dramatically. The problem, of course, is attractive positions in the commercial world at the masters degree level are causing our young people to leave their graduate work before completion of the Ph. D. The end result of this phenomenon is the depletion of faculties, which increases the teaching load on the remaining faculty, reducing the attractiveness of a young faculty career compared to industry, and exacerbating the problem all the more. Because of our concern for this problem, we have not only expanded our graduate fellowship program to 120 but are providing departmental grants to be used flexibly by department chairmen for the activities of non-tenured faculty. We are now providing $1.5 million a year in $25,000 grants for this purpose.

Finally, the capability of our colleges and universities to invigorate the scientific and engineering base for America's economic competitiveness rests on the quality of the K-12 school system. Deficiencies in the mathematics and science programs are well-documented by the National Science Board's Commission on Precollege Mathematics, Science and Technology and many other groups. Unless these deficiencies are remedied the entire structure of American science and engineering will inevitably suffer.

An even broader concern is the need for our schools to prepare all young people for a life of productive work and responsible citizenship in an increasingly technological world. Here, the fascination of students and parents with computers provides an opportunity to re-invigorate mathematics and technology education. But the schools and the teachers need a lot of help.

Finally, with respect to the secondary school mathematics and science teaching problem, under IBM's faculty loan program, a number of IBM'ers are spending up to a year in a variety of helpful assignments in secondary school. We have worked with local communities to train teachers to respond to a tital wave of student interest in computing. For example, our Rochester, Minnesota Laboratory will this year train local high school teachers and make Personal Computers available to 6,000 junior high school and high school students in that community. We expect to expand our activities of assistance to teachers and school systems who need effective educational support if computers in the schools are to be of lasting value to the educational process. Mr. Frank T. Cary, Chairman of the Executive Committee of IBM's Board of Directors, serves as Co-chairman with Governors Hunt and duPont on the Task Force on Education for Economic Growth. Through this Task Force the activities of the private sector, the local and state communities are being encouraged and shared.

I hope this brief recitation of our concerns and activities will convey some of the sense of urgency we feel about addressing the combined problems of public education, university research, graduate and professional education and, the productivity and innovation rate of our private sector. The interdependence of these three sets of institutions: schools, universities, and companies, is higher than generally recognized.

In some cases, the universities have been the initiators of prospects for whole new industries. Microbiology is today's best example. In this case, serious attention needs to be given not only to the continuation of basic research in the plant and life sciences, but to the technologies that will be required to make the scientific breakthroughs pay off in jobs and wealth for Americans.

In the computer industry, while university scientists did play crucial, early roles in the industry's development, the rapid growth of the industry left the universities far behind. One must remember that the first Ph.D. in Computer Sciences was awarded in 1965. The industry employs professionals in the tens of thousands, a great many trained on the job. The graduate education system has simply not caught up with the industry's growth.

Thus, business as usual in the disciplines will not permit the most rapid response of the nation to its new economic opportunities and the most rapid diffusion of that opportunity across our population.

It is important to remember while industrial collaboration with universities and financial assistance to them is important and effective, its importance lies more in motivation and direction setting on both sides of the partnership than as a primary source of financial support. According to the National Science Board's recent report to the Congress, industrial support for academic R&D in the U.S. is at most less than 7 percent of the total.

Similarly, total industrial philanthropy to higher education for all purposes is less than 3 percent of those universities' operating costs. Thus, an important role for federal funding of our universities is to permit the universities to take action when, through collaboration with industry, they find they want to build new programs in an area they believe appropriate to their mission and to their skills and desires.

An excellent example is the whole area of manufacturing systems engineering. This is the area in which I believe the Japanese have the U.S. economy at the greatest disadvantage. Our universities are ready to respond. They will need government help. Title II of HR 1310, for example, provides the kind of authorization for matching support that could encourage additional industry assistance and give the universities the opportunity to move quickly.

Just such a program was recommended to the President by the National Productivity Advisory Committee, on which I serve. I believe this could make an important contribution to industrial productivity.

With respect to engineering education in general, the Senate should give serious thought to the policy basis that has sustained the government's assistance to our engineering schools in the past. I believe it needs some modernization and extension. The historical philosophy in federal agencies has been to support basic research in the graduate schools of our universities as one of the best ways to sustain a healthy graduate education capability. This is certainly the right strategy for the mathematical and natural sciences. It is less clear that this is a sufficient strategy for engineering education, even though engineers can and must make important contributions to basic research. Much of engineering education deals with the practice of engineering in very complex and difficult problems, of which a highly automated manufacturing system is a good example. Here the educational investment needs to be explicit and not shielded behind other less-relevant purposes.

Of course, most of the financial support of our engineering schools comes from the government's mission-oriented agencies, which fund work related to real, practical problems. Unfortunately, these real problems of our military and space agencies often have little in common with the high-quality, low-cost, high-volume environment of the private sector. Indeed, while I believe the government mission agency support of engineering is an excellent driver of the sophisticated technology conent, if often ill prepares students to be productive quickly in the commercial sector.

Again, I believe legislation along the lines of Title II of HR 1310 would make explicit the authority to fund the kinds of educational investments engineering schools and industry together are eager to see.

Let me comment, finally, briefly on two other questions.

The first has to do with the research equipment and facilities at the universities. The obsolesence of this equipment is a well-documented fact. Most studies say the shortfall would take approximately $2 billion to remedy. This would not quickly be accomplished, but it is important that a quick start be made. The usefulness of university research to industrial application depends upon the technical environment in which much of this work is done. With industry laboratories generally much better equipped than corresponding university ones, it is clear to those of us in industry that we have a serious imbalance in the funding of academic research.

I believe the universities themselves must address part of the problem. It will take courage to insist university projects be properly equipped, even if the number of projects be reduced. Is is my understanding much of the budgetary increase for the National Science Foundation in 1984 is aimed at permitting the universities to do this, with the consequence of regretable, but necessary restraint in the growth of participation in the academic research enterprise.

The second subject addresses the question whether there is a long-term shortage of engineers for our economy. I do not believe the conventional manpower estimates or economic analyses shed useful light on this question. It is often noted the Japanese train and employ twice as many engineers per capita as do we. How is this so? The Japanese use recently-educated, young engineers for a very broad variety of tasks, many of which we might consider technician-level jobs. The Japanese bring a superior skill and education to those jobs, and the benefits to their employers are quite evident.

In other words, I believe employers in this country would use substantially larger numbers of engineers if the employers had the management skill to use them properly and if the engineers were trained and motivated to address the real problems of a broad spectrum of employers.

It is necessary here to observe that much of the relationship between industry and our universities involves the large, research-oriented, high-technology company. The real fruits of the productivity revival will be enjoyed when the vast majority of innovative, middle-sized companies, too small to enjoy corporate research capabilities, are taking full advantage of what our universities could offer and are having the opportunity to influence the character of the education and career aspirations of the young engineers.

I believe the ability of the economy to absorb engineers depends not on the state of the economy, but the state of the engineers, their teachers, and their future employers. The problem we should attack is the quality and appropriateness of skill and motivation of our technically-trained young people, not some contrived effort by government to match the numbers of diplomas handed out to the number of vacancies in the employment offices.

A final note. We have been through a period of two years of debate on the federal role in education, science, engineering and industrial development. With the recent State of the Union message and the current budget proposals, I believe all sides in the public debate share a common aim and a common view on the relationship between science, education, research and economic well-being. There are wide differences on the specific methods and specific budgetary priorities. I am optimistic a consensus is building for federal and private actions, in concert with the states and communities that will build a solid basis for reversing the downward trend in our economic fortunes.

Senator TRIBLE. Thank you, Dr. Branscomb, for an excellent statement. I regret that we are faced with another vote on the Senate floor. Perhaps at this juncture we should recess and vote and return, rather than interrupt one of your colleagues' statements.

Gentlemen, again we apologize, but we have no control over the order of business on the floor of the Senate. We will, then, recess and return as quickly as we can.

[Recess.]

Senator TRIBLE. Dr. Kennedy?

Dr. KENNEDY. Senator Trible, thank you very much. I am glad to be before this subcommittee as president of Stanford, and as also one of the 25-year beneficiaries of the system of which you are now the architects. I will try to summarize my written testimony in the canonical 5 minutes.

The first thing I want to say is that we have a great deal to be proud of about the American enterprise of basic science. But we should pause to consider that today's successes are the results of yesterday's investments, and not today's. I think there are reasons to be troubled now, and my colleagues have outlined some of those. I shall not repeat them, but I agree with them; in particular, I endorse the statement laid on the table for you by the Association of American Universities, to which Stanford belongs.

I was asked to deal especially with some matters relating to alternative sources of funding, university-industry relations, and I will do so. But let me begin with just a very brief background piece, if I might.

We have a remarkable system for doing fundamental research in this country. It emerged, as you know, through the conversion of a military research establishment after World War II into something that is unusual in the degree to which the training of graduate researchers is mixed with the doing of research. That combination has produced something of really extraordinary vigor.

That is one end of what you can think of as a trajectory of innovation in the society. The other end is represented by applications research and product development in the industry sector. There are some real differences in the sociology of those two kinds of science, and that is why the whole matter of university-industry relationships is a difficult and challenging one.

Basic research in the universities—where, by the way, 70 percent of basic research lives—is publicly funded. It is characterized by very open and informal communication, and it is managed in terms that might best be called exploratory and rather loose.

By contrast, applications research, at the other end, is generally proprietary, not very open, subject to very tight and careful management, and financed not by public funds but by risk capital. We have evolved a system for going from one to the other which, although it may not be quite as rapid in terms of technology transfer as we might like, does put in each of the places the things that each set of performers knows how to do best. That system has worked very well.

A current event of considerable importance is a compression in that trajectory of innovation; that is, a tendency of the distinctions between the two kinds of work that I just talked about at the two ends of that trajectory to be blurred. Four forces have worked to bring that about.

The first is a genuine public concern about the rate of technology transfer, and the need to make that diffusion process go more quickly in the public interest. A second is the sense that a number of branches of science—from biotechnology to microelectronics—are ready for much quicker application because they are so vigorous and so exciting that they suggest their own applications, as it were.

Third, of course, is that the universities—the places in which most of the basic research is done—have noticed that over the past 15 years, Federal support for nondefense related research has declined by about 43 percent real over the past 15 years. That is enough to send my colleagues and me scurrying around in search of alternatives; And, of course, the private sector is where we are urged to look.

Finally, something very interesting is happening in the industrial sector as well; that is a new style of capitalization of high technology ventures. The new tax law changes 4 or 5 years ago have spawned a variety of new, high technology companies in which rapid and dramatic changes of value have been associated with the early possession of an idea.

When that kind of financial incentive exists, you are going to see a migration of corporate interest to the earliest stages of this trajectory of innovation, because it is perceived that great changes in the value of a corporate venture can take place if they are seen to possess important ideas. They do not even have to have products yet.

These new relationships produce significant problems and significant opportunities for universities and industry. My testimony explores some of the risks and the benefits. I guess where I come out is that the problems are small compared to the opportunities. By and large, the problems concentrate in the area of informal relationships between university researchers and new ventures, and not in the structure of more formal agreements, of the kind Dr. Branscomb and others have talked about, between larger companies and universities. The latter, by and large, have paid rather careful attention to some well-evolved academic policies for the conduct of research.

We have wanted, however, to make the university community a little more responsive to opportunity. As a result, there are some new models for institutions that get in between universities and industry, and improve our ability to deal with these problems and opportunities.

In my testimony I have emphasized two of these. One of them is a kind of funding consortium for research in universities that itself owns a development company, but has a management independent from any university. Capital appreciation resulting from the discoveries that are made is put back into university research.

A second is the center for integrated systems recently developed at Stanford. It is remarkable chiefly because it represents an extraordinary private-sector fundraising venture to support basic research on integrated circuit development that a number of different industries need. We have raised $14 million for the construction of a new research facility with participating companies who can have their own researchers—up to a limit—on the ground and share in the process of discovery.

University presidents and industry people are now getting together in increasing numbers to talk about the problems. Dating from the conference we sponsored at Pajaro Dunes a year ago this month, there is more and more agreement among industry people and university people that as long as there is openness of access, as long as universities manage whatever intellectual property rights they may hold in common with industry sensibly and industry does, too, and as long as the primacy of faculty obligations to the university are recognized, various models for interaction can serve to shorten the time taken for technology transfer and also enrich the universities' research programs. That enrichment must take place where basic research works best; namely, where apprenticeship and training coexist with the process of doing research. The dissection of that relationship worries me more than anything else.

There is one risk, Senators, that I really want to address as forcefully as I can. It is that all the sound and fury about university-industry relations, and the problems attendant to these relations, might spread the notion that somehow the private sector is really preparing to shoulder a significantly greater part of the financial burden for basic science in this country. It is not even close to doing that.

What we have is a situation in which some very interesting and exploratory new interests on the part of industry are changing the degree and character of its participation in some selected areas. But however interesting and promising these developments may be, they are not significant in terms of the broad resource needs of fundamental science. The great venture of American basic research really is a partnership of the universities and government. It cannot continue to exist without public support.

By way of informal example, in closing, I would point out that if you just look at grant and contract support for university research, private industry actually supports only about 4 percent of it. Dr. Branscomb's figure included some more general grants that come from the more philanthropic parts of industrial organizations—for which we are grateful, but which do not really count as research support.

A 1-percent drop in the Federal support of research activities at Stanford would require a 25-percent increase in the industry contribution. That is rather unfavorable leverage, and I think it illustrates the reality of the present dependence of our extraordinary basic research system on public sector support.

I will stop there, with thanks.

[The statement follows:]

STATEMENT OF DR. DONALD KENNEDY, PRESIDENT, STANFORD UNIVERSITY

Mr. Chairman and members of the committee, my name is Donald Kennedy, and I am President of Stanford University. Before I started doing that, though, I was a researcher in fundamental biology who for 25 years was privileged to be a participant in the remarkable system we have evolved for doing fundamental science in this country. So I am doubly honored to accept your invitation to discuss the future of that system, with special attention to the critical role of the National Science Foundation. I hope also to explore some of the issues—much talked about recently in the press—that relate to recent collaborative research ventures between universities and industry. I should add at the outset that my testimony complements that presented by Dr. Richardson on behalf of the Association of American Universities and other groups. Stanford is a member of AAU, and vigorously supports the position it has laid before you today.

Our national pride in the success of American science over the past half-century is well-justified. Our position of international leadership is documented by an increasing domination of major awards for fundamental work and of the world's scientific literature, and also by a flow of innovations that have multiplied agricultural productivity and stimulated technological advances. Yet despite these successes, many thoughtful observers of our national science policy are worried. Scientific investigation is a long and continuous process. Today's triumphs—like our frequent successes in the Nobel Awards—actually represent the fruits of past investments of talent and resources. They are not a measure of the likelihood of future success. That future depends on investments we are making now; and as my colleague has testified for the AAU, there are reasons to be concerned about the quality of these present investments.

Before returning to these problems, I want to lay a basis for considering the present state of our science and its future by examining some structural features of the enterprise we have built and the roles played by different performers in it. Much recent attention has been focused on relationships between research and development, between industrial and academic organizations. The products of industry represent a culmination of a long process of innovation with a characteristic trajectory. I want to examine that sequence briefly by way of background.

Phase one, that of basic research, normally begins in a university or government laboratory and is oriented toward the discovery and explanation of *phenomena.* This first phase is characterized by loose, informal organization, very open communication, including quick publication of all the details of an experiment. Examples of institutions in which it might take place would be university departments of biology or chemistry or physics, a laboratory like an NIH Institute, or a very special industrial organization like Bell Telephone Laboratories.

A second phase is best called application. It is focused on processes, and takes place in various settings: applied institutes, some university departments (of engineering, for example), nonprofit research organizations, and industrial laboratories. Communication may be restricted as proprietary interests become increasingly significant.

In the third stage, development, attention is given to practical application—including such matters as scale, rates, and means of economical production. The innovative emphasis is on products; the environment tends to be closed for proprietary reasons and tightly managed. Essentially all such work takes place in commercial laboratories.

The traditions, the style, and the people who do the work at the two ends of this spectrum stand in sharp contrast: as a social process, fundamental research differs dramatically from product innovation. About 70 percent of all the basic research done in the United States is performed in universities, which also do a little process or applied research and no product development at all. Industry, on the other hand, is responsible for over two-thirds of the total research expenditures in this country; but this activity is heavily concentrated upon product development. It includes some applied or process research, and only a small amount of basic work. That pattern also applies to support: despite its large total share of all national research and development expenditures, industry supports less than 4 percent of all university research.

Who does the rest? The answer is that the Federal government does. In the years following World War II, our national wartime scientific establishment was converted into a publicly-supported, university-based enterprise of most extraordinary character. It grew through the recognition of mission-oriented agencies (like the Department of Defense and the National Institute of Health) that fundamental research was essential to their aims, and also through the development of the National Science Foundation as an entity concerned explicitly with fundamental science. A major imprint in the developing structure was provided by the belief that—to quote Robert Rosenzweig—"enlarging and disseminating knowledge are equally important activities and . . . each done better when both are done in the same place and by the same people." The coexistence of graduate training and research in U.S. universities is, in the veiw of many, what has made our system for doing science so vital. In recognizing its accomplishments in the year that the Americans swept all the Nobel Awards, Suny Bergstrom—now a Nobel Laureate himself, then the President of the Swedish Academy—referred to the "democracy of American science." He meant the close coupling between apprenticeship and practice.

The dependence of this system on Federal funding is well-illustrated by an example that could be applied to almost any research university as well as my own. If federally-funded research at Stanford were to be reduced by 1 percent, a 25 percent increase in industry funding would be required to make up for the loss. Or—to alter the perspective a little—if Stanford were to support its present level of research without any government help at all, using our standard principles for utilizing endowment income, it would require an endowment of $3.75 billion—six times the size of the one we have now, and with every dollar of its income devoted to research at the expense of instruction. It is, in short, difficult to exaggerate the importance of public-sector support to this beginning segment of the innovation process.

The adequacy of that support now finds itself threatend by powerful influences. The first is not new; indeed, it was stated as a law by the physicist Max Planck that research inevitably becomes more expensive as one does more of it. Not only do we answer the easier questions first, we also develop techniques and instruments that enable us to ask more difficult and penetrating questions. For the universities, that presents a challenging problem of supporting growth. Just because we have added a superb department of computer science does not mean that we can drop linguistics. On the contrary, our linguists are now using computers! And for you as architects of our federally-supported scientific enterprise the challenge is just as great. One science after another is becoming big science; ground-based astronomy, particle physics, more recently organic chemistry and now molecular biology. Just at a time when the controllable elements of the Federal budget are being brought under sharp restraint, it is most important to retain our traditional scientific productivity. The improvement in the NSF budget is a welcome sign that this problem is recognized and understood. But it will have to be accompanied by improvements in research support on the part of the mission-oriented agencies as well.

The second influence has to do with the trajectory of innovation I described earlier. That trajectory has been dramatically compressed in recent years. The separation between an early, fundamental research phase, existing mostly in the universities and supported publicly, and a later phase of application financed by risk capital is starting to blur. There are several reasons for this compression:

A number of scientific disciplines are now being recognized as "ready" for accelerated application. Our perceptions of what is possible are sharpened in such fields; as a discipline matures in power and confidence, leaps from the laboratory to applications that once seemed intimidating become commonplace. That now appears to be the case, for example, in immunology and "genetic engineering" as well as in microelectronics.

There is a growing social awareness of the importance of scientific discovery to national productivity, and a consequent impatience with the traditional time requirement for technology diffusion. The message from the small amount of research we have on the diffusion of discovery is that we need better devices for speeding technology transfer.

Concern in the research universities over the recent retreat in public support of science has grown. Federal funds for non-defense research were reduced by about 43.7 percent in real dollar value since 1967 (this calculation assumes the President's fiscal year 1984 budget is adopted as presented), and a significant decline has taken place in the first two years of the 1980's. It is not surprising that the universities and university scientists are looking for alternative means of support.

The venture-capital financing of small, research-intensive companies in fields like biotechnology and microelectronics presents a set of new incentives. In the nearly four years since major changes were wrought in the capital-gains tax, the investment available for such ventures has jumped from an estimated $79 million in the mid-1970's to about $1.5 billion in 1982. Very large changes in value can take place with successive generations of private investment in high-technology firms, and larger changes still when the firms go public. So there are strong financial arguments for early involvement with a research idea.

The result is an entirely novel mixture of influences upon university scientists and their institutions. For the university itself, there are new and challenging pressures on investment policy (does the institution go into business with its own faculty?) on technology licensing (should the university license inventions to faculty-led ventures? to their competitors? and if yes, under what terms?) or research contracts with industry (what restrictions on communication are acceptable, and should there be full disclosure of terms?) and on policies relating to consulting, faculty conflict of interest, and the protection of graduate student interests. Many of the problems are simply not soluble by the institution alone. For the scientists themselves, and the "invisible colleges" that hold them together in national and international networks, there are other questions such as: how much can or should they guard against the withholding of information and exchange for proprietary reasons? how much involvement outside a faculty member's primary institutional affiliation is appropriate?

In general, I believe this new climate offers more opportunities than it does problems. What we must try to do is involve industry more productively an creatively with university research in a way that leaves the latter intact, instead of risking fractionation of the training and research components and the division of faculty time between on- and off-campus ventures.

As examples, let me cite two promising new industry-university collaborative ventures involving Stanford that have begun in two fields of science.

Within the coming weeks, Stanford will break ground for a new Center for Integrated Systems (CIS), dedicated to fundamental explorations of what would popularly be called microelectronic chip development. Its purpose, however, is not to get a jump on the market by developing the next generation of integrated systems, but to advance the state of knowledge by orders of magnitude.

Without industry support, CIS would not exist. With industry support, Stanford has an exciting opportunity to discover fundamental knowledge in an area full of promise. The basic arrangement is this: 18 leading industrial firms in microelectronics and physics each have pledged to contribute $750,000 for the construction of a building to house CIS. Once the building is completed, those firms will contribute annual dues to CIS. In return, those firms may participate in the CIS program by sending to CIS one visiting scholar, approved by Stanford, to work with the CIS faculty on fundamental research. We think this contact between CIS faculty and students and industry scientists will, in itself, be stimulating and productive. The rules under which research is conducted at CIS are quite clear: all work is subject to the same canons as all other university work. Thus a free and open flow of ideas and swift publication of results are its operating conditions.

Industry in general gains from such ventures by assuring that fundamental work in this area will be undertaken. The particular affiliated firms gain through their exposure to new ideas in these fields and to the faculty leaders who are asking the new questions. Perhaps most important, the sponsors have a chance to become acquainted with bright students, whose education we also hope to enrich through the center.

On the university side, a critically important feature of the CIS arrangement at Stanford might be overlooked by anyone unfamiliar with the peculiarities of government funding and private fund-raising patterns at universities in the past two decades. That feature is that industry is paying for a building. Federal funds for science facilities construction all but dried up in the late sixties; and as university presidents know to their sorrow, raising private money for bricks and mortar is increasingly difficult.

A second arrangement, providing a rather different model for the development of new industry-university collaboration, is the new non-profit Center for Biotechnology Research. It will fund research in genetic engineering and biotechnology, and is affiliated with a for-profit firm, Engenics Inc., which will seek to develop commercial opportunities in the same field. Six major firms collaborated in financing the new entities. A unique feature of the arrangement is that the Center for Biotechnology will hold 30 percent of the equity of Engenics, and the charter of the Center provides that any capital appreciation and dividends realized on Engenics stock will be devoted to the further support of basic university research as determined by the trustees of the Center.

Some press accounts of the founding of these two organizations mistakenly characterized it as an ownership venture by universities. Stanford is fortunate enough to be one of three universities to be awarded research agreements by the Center, but the conditions for the conduct of the research are the same as for any other industry-sponsored research programs. Stanford owns no equity in Engenics, nor will Stanford lay any special claim to research funds available from the Center. The six sponsoring firms of the Center and Engenics may have licenses to any patents developed in the Center's funded projects, but these licenses will be offered at commercial rates and in accordance with existing policies at the universities. This is something open to any sponsor of research; it is a perfectly normal arrangement.

The novelty of the research agreements with the Center for Biotechnology comes not from any special conditions developed by the universities, but from industry's willingness to form a new funding consortium for university-based research. The participation by the universities is unexceptional.

These new forms of industry involvement in university research did not emerge easily; they evolved out of a process of hard negotiation. The condition under which university research flourishes—open and free exchange of ideas—is really quite different from the proper and necessary secrecy that shrouds end-product development. The two ends of the trajectory thus do not merge easily. Sponsoring research is not the same as making a charitable contribution, and the same firms that make charitable contributions for philanthropic reasons, rightly insist on getting some return, even if it is long-term, from sponsored research.

For their part, universities have no objection if their research benefits business. Indeed, they rather like the idea, but they are zealous about ensuring that the conditions essential to free inquiry for teaching and research are not compromised.

As it turns out, the public is very concerned about these same things. Dramatic breakthroughs in recombinant DNA research a few years ago caused great excitment, prompted new commercial research ventures, and even evoked some interesting flutters on Wall Street. In some quarters, there was alarm at the implications for universities. Premature press reports of new industry-university arrangements raised anxiety levels. A thoughtful paper at Harvard that laid out some important issues for consideration was widely misconstrued as announced policy. Some concerned observes seemed ready to conclude that universities were about to yield en masse to commercial seducation.

Although the publicity was focused on biotechnology, the fundamental issues underlay other research as well. Concerned that there was a pressing need for deliberation on the cluster of issues raised by the attention being given to industry-university relationships and encouraged by the hope that we might enter a new era of improved industry patronage for university research, five university presidents, joined by university researchers and by representatives from industry, large and small, met at Pajaro Dunes, California on March 25-27 of last year.

The conferees labored through some hard discussion about industry-sponsored university research. Though the exchanges were sometimes spirited and far-ranging, we were gratified at the consensus that the fundamental values of free and open conduct of university research must be maintained. Our industry colleagues understood and fully agreed with the academic priorities; they took the far-sighted view that any short run gains that might accrue from distorting the academic progress at universities would be offset by the decline in creativity of university-based science.

The statement issued at the end of the conference addressed some critical areas:

Research agreements.—Universities and industries should maintain basic academic values in their agreements. Agreements should be constructed so that secrecy will not harm the progress of science, interfere faculty choice in subjects of inquiry, or divert faculty from their primary obligations to teaching and research.

Patent licensing.—Universities should administer patent programs in a manner that conforms to the public interest and to the universities' primary commitment to teaching and research.

The university and its faculty.—University professors have long associated with companies through consulting and other types of relationships. Such interaction can have significant advantages to the university, to the faculty member, to the company, and to the public. Notwithstanding these benefits, professors' relationships with commercial firms should not be allowed to interfere with their overriding obligation to the university to fulfill their primary responsibilities of teaching and research.

These new university-industry relationships are exciting and full of promise. Like many important changes in the way we do things, they do not lack for controversy. In general, I am reassured that we can interact in new and creative ways with industry, accomplish significant improvements in the rate at which new technologies are transferred into human service, and do so without sacrificing the extraordinary character of American basic research.

But there is one risk, Mr. Chairman, which I wish to address as forcefully as I can. It is that all the sound and fury about university-industry relations will spread the notion that somehow the private sector is preparing to shoulder a significant part of the financial burden for basic science in this country. It is not even close to that; on the contrary, it is changing the degree and character of its participation in a few selected areas. However interesting and promising these developments may be, they are not significant in terms of the resource needs of fundamental science considered broadly. The great venture of American basic research is a partnership of the universities and the government, and it cannot continue to exist without public support.

Turning to the specific matter of the President's budget for 1984, I want again to emphasize my full endorsement of the testimony presented by the Association of American Universities. The Administration has proposed much-needed increases in some of the programs supporting basic research, and we hope the Congress will agreed to these Administration proposals. Although we find much to applaud in the President's budget, it is hard to avoid noting that certain areas—particularly the biomedical and social sciences—have not fared so well.

I would like to close by offering the following summary points and recommendations:

The success of American science can best be assured by vigorous support and adequate funding of the basic research programs of the NSF and other agencies, including as a high priority the basic research programs of the mission-oriented agencies.

The partnership forged between the federal government and the nation's universities has produced a remarkably efficient and effective science. Sustained excellence in science will require institutions capable of producing that excellence.

One of the significant features of basic research in America is that most of it is done at universities, which also train the next generation of scientists. This link between research and training should be supported through adequate scholarship and fellowship programs.

It is of paramount importance that the federal government, pressed by tight budgets, not try to purchase science at bargain rates by forcing universities to assume a greater proportion of the costs of government-sponsored research than they can reasonably be expected to bear. Specifically, the federal agencies should continue to reimburse full indirect costs as properly accounted for under OMB Circular A-21.

The federal government should move rapidly to repair the long neglect in instrumentation and facilities. Dr. Keyworth, the President's Science Advisor, was right when he recently said, "Over the past twenty years, our academic institutions have grown shabby. With few exceptions thay have become less and less attractive places to pursue research. Equipment and instrumentation are not as good as that in national labs, or in many industries. Somehow, we have arrived at the indefensible position of creating the poorest climate for research in the place that ought to have the best."

The federal government must reaffirm its role as the dominant—in some fields, the sole—source of funding for fundamental science. Industry-university collaborative ventures should be encouraged under the proper terms, but it must be recognized that industry support will only supplement and not replace federal funds.

Thank you, Mr. Chairman, for the privilege of appearing before this distinguished committee.

Senator TRIBLE. Thank you, Dr. Kennedy. In order to accommodate my distinguished colleague from Alabama, I would like to call on Dr. Bartlett next, and we will move forward quickly. Thank you, Doctor.

Dr. BARTLETT. Senator Trible, Senator Heflin, let me first thank you, Senator Heflin, very much for those characteristically warm words of welcome. I appreciate them very much.

Senator HEFLIN. By the way, I did not know it until just a while ago, but we have other Alabama connection here. Dr. Branscomb's grandfather was from Alabama. His grandfather and my father were both Methodist ministers and were great friends, and from the union of the Branscombs in Alabama has come forth some distinguished Americans, including Dr. Branscomb's father who was Dr. Harvey Branscomb who was chancellor of Vanderbilt University. Some of you might not know that.

So he has uncles and aunts, including Dr. Louise Branscomb, who is one of America's greatest female physicians who lives in Birmingham. I hope you get to know her.

Dr. BARTLETT. We are going to get the latest member of the family back to Birmingham this spring for a rather important event.

Gentlemen, to try to characterize the condition of American university science and advanced training, and then in that context, to comment on our special circumstances in Alabama, and then relate all of that to the NSF fiscal year 1984 proposed budget and finish it in 5 minutes would daunt the author of the Gettysburg Address himself, but fools rush in.

I would approach the role of the NSF and the condition of university science, including engineering science, in a somewhat different way from my distinguished colleagues. My perspective is from a region in transition, a richly endowed region with great potential for contributing more to the basic economy and technological strength of our Nation. But a region where educational and scientific capacities are not yet adequate to reach our potential.

The University of Alabama System operates one of the great biomedical centers in the Nation, and we are strongly competitive for NIH funds. But we are underdeveloped in advanced, physical, and engineering sciences.

American science, after World War II, grew in strength steadily until 1969–70. During that time, the Nation's defenses came to rely on our leadership in science and engineering. It became part of our national image and part of our image in the eyes of others.

Then during the 1970's for all kinds of reasons, we went through a process in science that was parallel in many ways to what was going on in the auto and steel industries. We lived off the capital investment and momentum of earlier years. Our plant equipment grew old behind a facade of size and strength, and our training programs were, in some areas, decimated.

Now we must regain momentum. Our long-term military strength and our position of world leadership in science and technology is at stake. But just as compelling, the future of our economy is at stake. The prosperity we seek and the quality of life for which we hope require a new commitment to science and engineering, education and research.

An 18-percent proposed increase in funding for NSF plus other stirrings in the Congress, with which the chairman of this subcommittee is certainly deeply involved, suggest that we may be ready to move. For us in Alabama, the problem takes on special characteristics.

Our State is well-endowed with fossil fuels and useful minerals. We have major water resources, forests and fertile land, but for a variety of historical reasons, we are economically relatively underdeveloped. If we are to achieve the potential of Alabama and of other States in our region, if we are to make our contribution to national prosperity, our universities must expand their research and training in science and engineering.

Nationally, the base of our scientific strength must expand to broaden the base of our economic strength. Now, that brings me to the immediate issue: the National Science Foundation, its programs and its budget.

First, our country needs a greater number of our ablest people trained in the most modern laboratories as teacher's and researchers in our universities. While the public in recent years has been bemused by the apparent glut of Ph. D.'s in the humanities, we have quietly been developing major shortages of the Ph. D.'s and others with advanced training in a variety of fields. For example, engineering, computer sciences, and energy resource-related disciplines generally.

The new teacher-researchers we need are not in the training pipeline in sufficient numbers, nor are enough of those now being trained working with up-to-date state of the art equipment. The proposed NSF budget for fiscal year 1984 recognizes some of this need to support a growing number of fellowships, and is an encouraging initial step.

Certainly, fellowships by themselves will not attract people into graduate study, but we will not attract adequate numbers without major fellowship programs. And the NSF example should now be followed by mission agencies. And incidentally, some of those mission agency fellowships should be assigned directly to institutions.

The proposed NSF grants to young investigators serve a similar service. They respond to several years of debate and discussion in the science community as to how young people beginning their careers can be encouraged to stay in research and training. It recognizes that the great advances in instrumentation and equipment have had an enormous impact on costs for launching new research, as we have been told earlier in the afternoon.

Instrumentation funding is increased in the NSF budget, but we should be clear on the magnitude of the challenge. Our laboratories have been depleted by years of inadequate investment, and it will take years and many hundreds of millions of dollars to rebuild our laboratory capacity.

Perhaps the greatest single problem in the physical sciences for institutions like ours in Alabama is to bring together the critical mass of instrumentation that will attract, hold, and make productive growing numbers of dynamic and creative scholars who are essential if we are to expand the research and advanced training we need.

In boosting our Alabama universities to a higher level of service for the economy, Federal support is vital. I echo the words of President Kennedy: private funds surely can help. For example, in our campus at Huntsville, high technology firms in the city recently rallied to provide engineering instrumentation worth about a half million dollars for one particular laboratory.

The major high-tech park in our region, Cummings Park, is across the street from the campus and faculty, and students frequently work on both sides of the street. At our campus in Birmingham, every aspect of the schools of business and engineering and of the medical center is geared into the economic life of Birmingham, and that fact was dramatized by the leadership of the community in building at UAB a new engineering and business education center.

In Tuscaloosa, as reported on CBS national television last night, the University of Alabama formalized a pioneering multiyear agreement with General Motors and the United Auto Workers. All three are to work together to increase productivity and efficiency in the Tuscaloosa-Rochester products plant.

University and industry cooperation is sought by both sides, and it is important but it does not replace the need for Federal research support. The Federal Government is the crucial agent for the support of basic research no matter how our State may acknowledge the need for stronger advanced research and training and no matter how carefully industry and university interact.

We in Alabama support expanding levels of NSF research funding even though at the present time we may not be sufficiently successful in competing for those funds. In the future we shall be better able if those funds are there in stable amounts and growing. Meanwhile, we press ahead, building our basic capacity, and for that we need the other National Science Foundation programs to be strong and diversified in their purposes.

Thank you, sir.

[The statement follows:]

STATEMENT OF DR. THOMAS A. BARTLETT, CHANCELLOR, UNIVERSITY OF ALABAMA SYSTEM

Senator Gorton, Senator Heflin, members of the committee, thank you for the opportunity to comment on the proposed budget for the National Science Foundation.

I approach the role of the NSF and the condition of university science, including engineering science, in a somewhat different way from my two distinguished colleagues. My perspective is from a region in transition, a region with great potential for contributing more to the basic economic and technological strength of our nation. But our educational and scientific capacities are not yet adequate to move our richly endowed region forward as a greater source of wealth and strength to the nation. The University of Alabama System operates one of the great bio-medical centers in the nation, and we are strongly competitive for NIH funds. But we are underdeveloped in the physical and engineering sciences.

The history of American science since World War II has been turbulent. In general until 1969-70, it was an era of strong growth. The nation's defense came to rely on the strength of our sciences and engineering. Such strength became part of our national self-image and our image in the eyes of others.

During the 1970's, for all kinds of reasons beyond our scope today, we went through a process of science parallel in certain ways to what was going on in the auto and steel industries. We lived off the capital investment of earlier years. Our plant and equipment grew old behind a reputation and facade of size and strength.

Now we must regain momentum. Our long-term military strength and our position of world leadership in science and technology is at stake. And a new imperative has been added. The future of our economy is also at stake. The prosperity we seek, and the quality of life for which we hope, require a new commitment to science and engineering education and research.

Such a commitment alone cannot solve the nation's problems. But neither can they be solved withoug growing strength in research and advanced training.

For us in Alabama, the problem takes on special characteristics. Our state is well-endowed with fossil fuels and varied minerals. We have major water resources, forests, and fertile land. But for a variety of historical reasons we are economically underdeveloped. We are below national averages in per capita income, and below many national averages that reflect levels of consumption and educational achievement. But our potential is great.

Achieving that potential for Alabama, and for other states in our region, requires that we greatly expand the capacity of our universities in advanced research and training. If we are to make our contribution to national prosperity, our universities must expand their research and training in science and engineering. And what is true in Alabama is true in a number of states and regions. The base of our nation's scientific strength must expand to broaden the base of our economic strength.

That brings me to the immediate issue, the NSF, its programs and its budget. First, our country needs a greater number of our ablest people, trained in the most modern laboratories, as teachers and researchers in our universities. While the public in recent years has been bemused by an apparent glut of Ph.D.'s in the humanities, we have quietly been developing major shortages of Ph.D.'s and others with advanced training, in, for example, engineering, computer sciences, and in energy resource-related disciplines generally.

Nationally, in too many fields, we have let our graduate programs stagnate. The new teacher-researchers we need are not in the training pipeline in sufficient numbers. Nor are they trained in sufficient numbers on state-of-the-art equipment. The proposed NSF budget for fiscal year 1984 is an encouraging step forward. It recognizes the need to support a growing number of fellowships.

Fellowships by themselves will not attract people into graduate study, but we won't attract adequate numbers without major fellowship programs. Expansion of the NSF fellowships program is extraordinarily important. NSF's example should be followed by mission agencies if our national response is to be adequate.

The proposed NSF grants to young investigators serves a similar purpose. It responds to several years of debate and discussion in the science community as to how young people beginning their careers can be encouraged to stay in research and teaching. It recognizes that the great advances in instrumentation and equipment have had an enormous impact on costs for launching a new researcher. One AAU study 2 or 3 years ago suggested that the cost over the last 12 years in certain fields might have grown as much as ten times in the expense of equipping a new investigator.

Instrumentation is increased in the NSF budget. But we should be clear on the magnitude of the challenge. Our laboratories have been depleted by years of inadequate investment. It will take years and many hundreds of millions of dollars to build up our laboratory capacity again. Perhaps the greatest single problem in the physical sciences for institutions like ours in Alabama is to bring together the critical mass of instrumentation that will attract, hold, and make productive, the dynamic and creative scholars that are essential for research and advanced training.

NSF support for instrumentation is essential and must be sustained and enlarged in years to come.

In boosting our universities to a higher level of service for economy, federal support is vital. Private funds, to be sure, can help. For example, at our campus in Huntsville, high technology firms in the city recently rallied to provide engineering equipment worth about one-half million dollars. The major high tech park in our region, Cummings Park, is across the street from that campus, and it is difficult to know when one goes from one to the other. Students frequently work on both sides of the street during their university careers. Institutions on both sides of the street depend on the other for essential support. But, the task of building the buildings and equipping the laboratories to do state-of-the-art training cannot come from industry who must, after all, price their products competitively without adding a margin for philanthropy.

On our campus in Birmingham, every aspect of the schools of business and engineering and of the medical center is geared into the economic life of Birmingham. That fact is constantly emphasized and dramatized by leaders in the city.

In Tuscaloosa just last week, the University of Alabama formalized a major multiyear agreement with General Motors and the United Auto Workers. Under this novel arrangement, the United Auto Workers, General Motors management, and specialists from the university will work together to increase productivity and efficiency in the plant. All three parties are making a direct investment and all stand to gain if the project is successful.

What I am suggesting is that university and industry cooperation is sought by both sides. And it is important but it does not replace the need for federal research support. The problem is whether our universities in Alabama will have the capacity to respond to the open invitations that come to us from the business community.

Historically, state governments have contributed significantly to our research enterprise by maintaining the basic capacity of the university. Funding specifically for basic research has been typically a federal responsibility. The federal government is the crucial agent for our support of basic research no matter how much our state citizens may acknowledge their need for stronger advanced research and training. No matter how carefully industry and universities may interact to ensure mutual support, an essential component for success must come from the federal government in its support programs. The NSF has a critical role to play in ensuring that the universities are able to make their contributions to the economic strength of our country as well as to its strength in military technology.

We in Alabama support expanding levels of research funding. Even though at the present time we may not be adequately successful in competing for those funds, in the future we will be able to compete for NSF research funds if they are stable and growing. Meanwhile we will press ahead building our basic capacity in people and facilities. For that we need NSF programs that are strong and diversified in their purposes.

Senator TRIBLE. Thank you, Doctor.

Dr. Penzias.

Dr. PENZIAS. I am Arno Penzias. I am vice president of research at Bell Laboratories.

My colleagues have already, and quite appropriately, remarked on the importance of the central role of Government in supporting the universities and, in turn, the central role of the universities themselves as the agency and engine of success in science and technology for our country. Those remarks are very appropriate and I certainly agree with them.

Rather than repeat what has already been said, in the interest of time and since I am the last speaker before it is your turn to ask questions, let me just turn the floor over to you, if I may, and ask what it is you would like to ask us. I think that my prepared remarks are here already, and I am interested to know what else you would like to know.

[The statement follows:]

STATEMENT OF DR. ARNO A. PENZIAS, VICE PRESIDENT OF RESEARCH, BELL LABORATORIES

My name is Arno A. Penzias, I am vice president for Research at Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

I am pleased to have this opportunity to comment on the Administration's proposed budget for the National Science Foundation for fiscal year 1984 and on those related issues of interest to the Subcommittee.

I believe these hearings are particularly timely because of the growing national interest in research and development (R&D), as part of the broader issue of high technology. This is a subject that seems to be on everyone's minds because of its link to economic growth and international competitiveness.

I find it somewhat unfortunate that once again it takes a crisis-like challenge to remind us all of the abiding value of scientific research and engineering skills to society.

Nevertheless I am encouraged by much that is taking place today and being reflected by the interest of this committee. There is no doubt that we have entered an era in which high technology—technology that is research-intensive and demanding of a high level of education and technological skills—will have an increasing economic impact both domestically and internationally. Since we see an increasing amount of international competition in this field, in discussing the Federal support of research as reflected in the NSF budget, we are talking about matters very critical to America's long-term success.

Clearly, the framers of the R&D budget have recognized the importance of research and development. Total Federal funding for R&D in fiscal year 1984 is planned to grow by $6.9 billion or 17 percent about the 1983 level. At a time of economic stringency this growth in R&D is a strong vote of confidence for science and technology. Also significant is the increase in basic research funding with emphasis on the support of research in the physical sciences and engineering. By any standards, the $6.6 billion obligated for the conduct of basic research in 1984 is a significant sum. It represents 10 percent growth over this year's budget, which accounted for more than 65 percent of the total national investment in basic research. The NSF budget is an important part of the total R&D budget because it supports primarily basic research in a wide range of scientific disciplines through grants to scientists and engineers in academic institutions.

Therefore, the 1984 NSF budget of $1.2 billion obligated for R&D, which includes an 18 percent increase for basic research, is of particular importance. With its special emphasis on disciplines such as mathematics, computer and material sciences, as well as electrical, computer and chemical engineering, this budget supports research that has the potential to contribute significantly to long-term economic growth and particularly to the competitiveness of our high technology industries.

I think that the kind of basic research we are talking about in these programs is properly the role of the Federal Government. It is fundamental, long-term, high risk research that few industrial companies have the resources to support. But its results and their future applications could eventually lead to significant payoffs in advancing America's economic strength and technological leadership.

Probably the most important reason why a strong NSF budget is vital to the nation is that its funding of research in academic institutions has a critical impact on the training of the next generation of scientists and engineers. Therefore through NSF support we are not only reaping the benefits of new knowledge, but preparing new minds. We are developing our most important resource. Our system of combining research with graduate education in this country is a powerful tool for technological, economic and social advancement; one we should strive to support and improve in every way possible. To do this we must also lay the groundwork by our attention to earlier education in science and mathematics.

Let me highlight a few programs in the NSF budget and the support they are receiving.

I believe that the Presidential Young Investigators Awards is a worthy new initiative. These awards, aimed at encouraging and supporting young faculty at research universities, are also designed to improve ties between such universities and industry as they involve matching grants from the private sector. Approximately $5 million will be allocated to first-year support for up to 200 of these young scientists. The awards will average about $30,000 per year. I am confident that industry will respond with matching funds.

I might just mention at this point that we at Beil Labs recently announced a new $2 million fellowship program to support doctoral students in technical fields important to communications and information technologies. When in full operation program will have 100 fellowships in effect annually, each fellowship lasting on the average four years or until the time required to complete the Ph. D. program.

Returning to the NSF program, I am please that its budget for Science and Engineering Education will increase by $9 million or 30 percent, and that $5 million of that will be used to expand the program supporting the training of secondary school science and math teachers. The balance of that increased funding, $4 million, will be used for another important purpose, raising the stipend and cost-of-education allowance of close to 1,400 graduate fellows.

On a broader note I am encouraged by the additional $64.6 million going to Mathematical and Physical Sciences support and the increase of $22.2 million for Engineering research, both budgets rising by 22 percent over the previous year. In the later program the emphasis on research in microelectronics and work related to automated manufacturing, robotics, biotechnology and the chemical process technology will contribute to advancing technologies important to the nation's technological competitiveness in the years ahead, as well as open up new areas of economic opportunity.

The same is true of work being supported by substantially increased funds for work in molecular biology, genetrics, plant biology and neuroscience research. These are all fields of enormous long-term promise in which our current knowledge is only in its infancy.

Rather than discuss specifics of the budget and offer opinions as to the relative importance of the programs and the adequacy of their support. I would prefer, in keeping with the interest of this hearing, to devote the balance of my statement to a broader discussion of the issues related to research and its support.

One of the reasons why we are here, and why there is so much discussion in the Congress, in the Administration, and throughout the country in general about science and technology—or simply "High Technology" if you will—is the air of crisis I mentioned before. Domestic and global economic conditions and the intense competition that acompanies them have awakened many to the fact that economic growth is inexorably tied to increased productivity. And that in turn is dependent today on the value added by technology. At the some time many people feel that our consumption and our expectations have begun to exeed our ability to meet them. While we have made many remarkable strides in science and technology over the past few decades, we have not reinvested adequately for the mid-term and long-term, neither in physicial plant nor in people. And some of that deficiency is showing up.

When one discusses the research budget, as we are doing today, it is essential to recognize the importance of the long and medium-term investment. Basic research is inherently a long-term investment. The return on that investment is in the form of a knowledge infrastructure on which we build our successful technologies. We can see this clearly if we trace the research behind all our successful telecommunications and information technologies: microelectroncies, microwave, fiber optics, lasers, computers, satellities, and so forth. In all these technologies we are constantly turning back to basic research to find ways of improving them—making them better, more efficient, more reliable, more affordable.

Admittedly, basic research is a high risk venture and many of its returns are either of the kind that offer a broad public good or are not easily or readily capitalized on by industry. That's why we look to government and the kind of public investment we are discussing today in the form of the NSF budget.

Additionally, as you know, industry's role in this is growing too, both in terms of individual corporate investment in research and in industry's growing number of cooperative research programs with universities and even with each other. These are both significant and encouraging directions. And they deserve and need to be motivated and nurtured further by government policies, such as tax incentives and enlightened regulatory policy.

At this point let me emphasize the most important contribution the government can make. It can develop and pursue policies to help straighten out the economy. The best things for research and development are a stable dollar, low interest rates and a healthy investment climate. When we have these R&D will increase, as will our programs with universities.

I am not an expert in these matters, so I will not go into detail on them. But I know that the Administration and the Congress have much expertise and interest in such policy areas and are pursuing them vigorously. Also, there is a growing movement throughout industry for accord and action on such matters. So there is a good basis for developing consensus and pursuing truly bipartisan, statesmanlike policies and programs.

Along these lines there are many worthy observations and recommendations. A number of these are discussed in the Fourteenth Annual Report of the National Science Board, a report on University-Industry Relationships. Also The Business-Higher Education Forum will be issuing soon a Report to the President of the United States on America's Competitive Challenge: The need for a National Strategy. This will be a very thoughtful, constructive study containing many worthy recommendations.

While I fully support this climate, discussion and action to get America moving again, largely on the basis of advancing our science and technology, let me interject a note of caution. I believe we can, and we will recapture much of the technological and economic vitality that we seem to have temporarily lost. Still, we also must recognize that the kind of undisputed technological and economic leadership we enjoyed from the end of World War II until recent times will probably not return. We should face the fact that our almost total dominance during that time was, in some respects, a brief accident of history. From here on we face the challenges of competitors from many nations who, if they do not have all our advantages, do have substantial talent, resources, and organization to be serious competitors in a number of technologies and in almost every market.

This competition embodies an essential lesson we must learn to live with: From the standpoint of science and technology—discovery and invention—we live in an open world. Since no nation has a monopoly of ideas and talent, all nations should cooperate and help each other to advance knowledge and skills to their mutual benefit.

But at the same time, this free flow of knowledge and know-how gives advantage not only to the pioneers and original thinkers, but also to those who are clever, resourceful and aggressive in other ways—in transferring technologies in a timely manner into products with high market receptivity, in marketing, trade and the ability to understand people, their cultures and their needs. In these things we in the United States have suffered many shortcomings. Our limited success as global marketeers and traders, may be due in part to the very size and success of our domestic markets. As long as those markets were the mainstay of our business we could afford to be insular in our attitude and approach toward global marketing. Developing and packaging technologies specifically for foreign sales became secondary to selling American goods overseas. There is a difference, and others—noticeably the Japanese whose survival has always depended on trade—have recognized it and benefited accordingly.

In relatively recent years, however, we have also become a trading nation. As Treasury Secretary Donald Regan pointed out recently: Exports of goods and services as a share of our gross national product doubled between 1970 and 1979, accounting for 12 percent of the GNP.

But at the same time it should also be noted that our share of world exports of products in many of the high-growth, high-technology industries—computers, telecommunications, advanced electronics, biotechnology, aerospace and so forth—has declined sharply.

It has been said that we are entering a new ball game, one in which the playing field is an interdependent competitive world. It is also a world in which new knowledge and new technologies—high technologies if you will—will drive economic progress, and in which those technologies must be formed and focused to meet many new needs. Notable among these needs will be those of the more than three billion human beings who are still a long way from enjoying the benefits of a high technology age.

How do we in the U.S. best meet this multiple and complex challenge? I know of no simple answer, but I would like to conclude by highlighting one important direction our response must take, one directly related to our present discussion of research and budgets to support the education and training of our scientists and engineers.

The strongest base for America's future success is our people—their creativity, innovativeness and resourcefulness when challenged. But these qualities must be encouraged, developed and supported. We must be willing to invest in our people—in their education, in their future, and thus in ours. We must provide the training and the tools to allow them to understand, discover and invent. If we as a nation do this we will prevail and prosper—we will remain leaders in technology as well as in the other aspects of human endeavor.

My experience at Bell Laboratories convinces me of these beliefs and reinforces them constantly. Our successes have come from our ability to attract people with the best minds, with the best educations, and place them in an environment that provides both the freedom to be creative and the focus to work toward constructive, clearly conceived goals. While we provide these people with consistent material support from our own resources, we depend on the universities as a source of new talent, a reservoir of basic knowledge to which we contribute and from which we draw.

All this leads me to believe that we can meet the foreign challenge with U.S. ingenuity and creativity if we are willing to make this investment in our universities and provide this opportunity. No nation has a smarter or more inventive people. It is up to us now to create the climate in which government, industry and our schools can invest in our people and support their considerable capabilities.

In conclusion let me emphasize again that the competition ahead will be difficult. We will be competing in many technological races, and many will be close. We may lose some. But we will win many. All told, however, it will be a long-term venture requiring long-term investments. I believe we should make such investments, and that they will pay off. What we are reviewing and discussing today is part of a good beginning. I believe we have begun to move in the right direction—and in any kind of race that's the first thing you have to do.

Thank you. I will be pleased to answer the Committee's questions.

Senator TRIBLE. Doctor, I think you would have a bright future in politics if your academic and business career came to an end.

Let me call on my friend from Alabama. Senator Heflin, do you have questions?

Senator HEFLIN. I am interested in the need for instrumentation in our colleges and universities as well as incentives to have the bright minds stay and become graduate students and to stay in the field of research and a combination of research and teaching.

This question of university contribution and the effect upon that contribution because of dramatic changes in instrumentation intrigues me and I think it is something that we must look at.

Do you want to expand on that a little further, Dr. Bartlett?

Dr. BARTLETT. Senator, the cost of equipping and maintaining modern laboratories has gone up dramatically, in part because we have gotten so good at designing extremely sophisticated instrumentation that will enable us to do more and more sophisticated work. Our very success means that our problem becomes greater in funding the infrastructure of science, in providing the facilities and equipment.

Our special circumstance in Alabama is such that we need to bring together the kind of laboratory capacity that will attract and hold our ablest people. Too often these very able young people find themselves having to go outside our region to pursue the advanced work which they want to pursue. Yet the fact is Alabama has very extensive resources to be developed.

Alabama does not yet have an adequately balanced economy, and the State will not be able to balance the economy adequately until the university capacity for advanced training and sophisticated research becomes of national standing in more and more fields.

We have some examples where we have achieved that standard and industry and social development has spun off in all directions, and that should encourage us, but we aren't going to get the process started, we aren't going to be able to break into the cycle unless we can bring together in key areas the kinds of sophisticated facilities we need; and the key to that, the heart of that problem is instrumentation.

Now some of that, it seems to me, we can hope to glean from Federal programs. Some of it will have to come from State efforts and some from private efforts. It will take all of those working together, but clearly that is at the heart of our concern, and it doesn't seem to me it is just a State problem.

It seems to me it is in the interest of the Nation because if we can succeed, then our capacity to educate our people, to pay taxes, to contribute to the level of the economy of the rest of the country becomes much greater. If you look at the pattern of private foreign investment in Alabama already, it suggests just how much of a contribution our State could make were we adequately developed.

Senator HEFLIN. I wonder if some type of a program by which industry playing a part in this through certain tax advantages couldn't work together and aid in this? I assume it is not just an Alabama problem but it is a problem that is nationwide. If some of you could furnish us with some type of proposal, you have tax lawyers and other people at the universities and you could think about a program that could be designed in this capacity to assist.

Dr. BARTLETT. If I may add one footnote to that, and then I suspect President Kennedy has another comment as well. During the time of the 1980 tax law being developed, some of us were very concerned about trying to create tax incentives for corporations to donate equipment as well as donate direct financial support for research in universities.

We made some headway but there is still a good deal more that could be done in making it attractive, in tax terms, for industry either to support some of its own research through grants to universities or to enter into collaborative arrangements with universities. It is a very interesting avenue to pursue.

There are now several programs in the country going on in what are called creative financing. The National Science Foundation itself has been very much interested in trying to identify ways where using leverage leasing tax arrangements, we could devise ways where industry could support instrumentation needs of universities more effectively. We need to explore all of those.

When we get through, however, we will find that they are still only simply a fraction of the solution to the problem.

Dr. KENNEDY. I would if I may, Senator, like to support my colleague in that, if only to add a couple of things that modesty may prevent him from adding. As you know, before you persuaded him to come down there, he was president of the Association of American Universities.

That association produced during his time there the, I think, most useful single document on the instrumentation crisis, and I would really urge that you and your colleagues examine it carefully. It is a very accurate assessment, all of us believe, of the situation as it stands.

Second, AAU also, I think, developed a very thoughtful position on tax law changes, including specifically a position that would have made the tax credit for industrial contributions to university R&D somewhat more attractive than they wound up in the compromise version.

Specifically, there are some provisions that exclude the rolling base of existing contributions from the part on which the tax credit may be taken. I think that if we simply got you and your colleagues a restatement of the part that was asked for and that we didn't get the last time around, it would probably constitute a proposal that we would make this time.

Dr. Branscomb may say something about this.

Dr. **Branscomb.** I wanted to add this. You are aware, of course, of the feature of the Economic Recovery Tax Act that provides a special tax benefit for gifts of equipment to universities for research purposes. I would make three comments about that.

It does have a strong effect. We are contributing more in the way of equipment than we did before. It would be worth the Congress watching rather carefully the regulations that are issued by the Treasury on that, particularly in the wake of the regulations recently issued in connection with the incremental R&D tax credit where Treasury seeks to exclude all those thousands of small software houses from the benefit, a decision that was announced on the same day the President made his state of the Union message about high technology industry.

The second comment I wanted to make is this. There are kinds of university equipment that are also used in the commercial world and elsewhere and in which it is reasonable to expect companies like mine to participate and we are participating.

But the universities depend very keenly on a great variety of very sophisticated, very specialized pieces of analytical or research equipment. Often that equipment is made by companies that have less than 500 employees and their only business is selling instruments to universities. In fact, those companies are typically started by people who left universities with a good idea.

Even if you make the tax treatment very generous for them to give the equipment away, even if they made money on it, which I can hardly imagine Treasury wanting to see, it is hard to imagine those small companies having a business incentive to give equipment away that saturates the only market they are in business to serve.

My final comment would be that even if that weren't the case, I think it is terribly important to leave the majority of the decision in the hands of the university investigator on what piece of equipment he wants and from whom he wants it, because that equipment is the soul of his project, and to make him the victim of corporate philanthropy and having to take whatever he is offered, which may not be the thing that is most suitable, is not going to be best for science.

Let's keep the universities in charge of the equipment they need. If I can add one more thought as to why that is important, an observation was made that this is a national issue and not a local one, and I believe it is more than just a resource issue for the university. Equipment plays a unique part in this strange but marvelous dynamic between the creation of knowledge and the creation of wealth.

The scientist, and the experimental scientist particularly, discovers some new phenomena, usually with an apparatus of his own invention and construction. The only one in the world that exists was built by this individual and the graduate students. Some faculty members, having made that discovery, would press on for further basic discoveries. Some others would become fascinated with this phenomenon and the little tool they built to discover it, and they would say, "I can build a better one than that, I can discover more with it. '

A few of those folks will decide maybe to start a basement company or make an arrangement with some commercial organization, and that apparatus which is an analytical device for observing nature will turn into a commercial instrument. About that time, the scientists discover that an instrument used to observe nature can be turned around and used backwards, to control nature, and almost all of the production tools that we have in modern industry had their origins in the inverse.

The most obvious example in electronic chipmaking is electron beams to write patterns on silicon wafers in order to make integrated circuits. Those tools are electron microscopes run backward, backward in function; they have the opposite function. Instead of looking to see what is there, they are writing what is there, and so the vitality of that instrumentation industry is crucial to the dynamic conversion of discovery into, eventually, tools of production.

Senator **Heflin**. One of the things we hear a lot about today is research parks. I think every State is trying to get research parks. Research triangles have occurred, and some of them have been quite successful, particularly relative to high technology.

We have had one in Huntsville, which Dr. Bartlett mentioned. If you had research parks in which industry and university are interacting and providing instrumentation which that industry may use and which would update the university's instruments, the tax advantages might occupy a unique position in that.

I don't know all the tax advantages, but for example, if there is joint use, you might allow, instead of a depreciation schedule, the sale to occur where it could be expensed out per year and perhaps some other things that could be useful in bringing this about.

There are a variety of means that perhaps ought to be explored, and we would be interested in seeing a paper that was prepared pertaining to this.

Some have been adopted and some have not. Doctor?

Dr. **Penzias**. If I may respond to this, I think my concern very much is with American competitiveness. We are facing a Japanese challenge, and one of our greatest strengths is our ability to think fast on our feet. Much of what I have heard in the past 15 minutes has gone against that principle, I am afraid.

At Bell Laboratories, as vice president with all the budget at my command, I do not go out and buy an electron microscope, a free-electron laser, a Cray computer for my people and then try to hire people to use it. The success of Bell Laboratories research at this point has come from exactly the opposite approach, that the entry level scientists, and I think Dr. Branscomb mentioned this also, the individual desperately wants to do something which his or her talent and ingenuity demands, and then there is the fight to instrument it, not the other way around.

This avoids rigid downward planning, however attractive it may be. I think that universities would feel that they are more attractive if they only had a high energy machine or if they had a bigger computer center. Any one of these things might be quite true and they might be able to attract some people; but my feeling is that the very best people are attracted because there are other bright people there. They are attracted by the high quality and the spirit of the ideas that apply at that time.

The central role that the NSF plays in keeping America's competitive edge where it is is due in part to its lack of planning. The NSF doesn't decide this year we are going to provide 40 IBM computers or 200 accelerators or what have you. What they do is they solicit proposals from individual scientists who then ask for whatever they want, and the flexibility of those dollars is far more valuable than an equal number of hidden tax dollars which don't appear in somebody's budget and are paid by the Federal Government through write-offs because somebody takes it off their W-2 form or whatever.

So I want to say a nice word for the NSF before we get off on all these other things. The NSF has a central role in supporting universities. The money is unstructured. It has no gimmicks associated with it. It is provided to the best and the brightest people, and those brightest people attract others.

That is not to say that we don't need research parks. That is not to say we may not allow people to give equipment. My experience with equipment is that it has a Barbie Doll quality. They can afford to give you the doll because of the price of the dresses. I know of no piece of equipment in the world that comes free.

Even a computer program requires maintenance. Software is the worst thing to give someone else because somebody has to keep fixing it. All you do is try it a few days, the program bombs, and you are back to hiring a programmer. Equipment takes up floor space, and so on.

The thing I am most depressed by when I read Physics Today ads for universities is "We would like to hire atomic physicist who is interested in X-ray fluorescence to use our spectrometer. That is not guaranteed to get the brightest individual to that university, and I would rather get the brightest individual and give him or her a second-rate spectrometer than the other way around.

That is not to argue that any of these other things are not right, but I have kept quiet long enough, and I don't want to use the "helicopter gunship" approach to solving people's wars. The big piece of hardware is easy to buy and pay for; the loyalty of the people is intangible but more valuable.

Senator **Heflin**. Well, I believe that problem can take care of the different approaches. One can't supplement the other without causing problems.

Dr. **Penzias**. Well, let me throw a word in for people against hardware, even though I have a lot of hardware of my own. Thank you.

Dr. **Bartlett**. That last throw-away comment was very important.

Senator **Heflin**. That is all I have.

Senator **Trible**. Thank you, Senator Heflin.

Dr. Penzias, let me pursue the idea you just put out on the table. How do we generate the people, solve the manpower problems, and generate the ideas that are essential?

Dr. **Penzias**. I think the NSF budget is taking a very important step in that direction, for the universities, my colleagues in the universities. We at Bell Laboratories depend on universities for a healthy two-way flow of people and ideas, very importantly, as I am sure Dr. Branscomb and his colleagues do and my other colleagues in industry.

The university people depend primarily on the NSF to support their research and to support their graduate students, and in the NSF budget there is not only more money for research but specific allocations to provide young scientists and students the support they need in order to get where we are going.

So I would say the kinds of things that are in this report, the kinds of things that are in the budget, as I understand it, are exactly the kinds of things we need to get where we are going. I can't guarantee that this is everything that we need, but it certainly is in the right direction. These are the kinds of steps I am very happy to see taken.

Senator **Trible**. Let me follow up your statement and respond to that question with a question that I would propose to the panel, to anyone who might wish to respond. As you know, in the NSF budget, certain areas have been singled out for substantial funding increases. Is this kind of targeting of funds an effective way to insure the best return on our investment? You seem to suggest that it might be. Is that a worthy approach, gentlemen? Does it, in fact, improve the return?

Dr. **Penzias**. This is more a university question.

Senator **Trible**. It is to the panel.

Dr. **Kennedy**. I do not mind diving into that in the least. I think every once in a while it may be necessary. I think it is a bad habit. I think that in general, agencies like the NSF and the mission agencies, too, especially those that are most experienced in managing research money, have a very good idea of how to take advantage of peer review and other processes to develop a pretty sound internal sense of their priorities and to gain consultation on it. I think that sense is likely to be right most of the time. It is pretty flexible. And by and large, I think it is best left to its own devices.

That is not to say that at particular times there may not be good reason for stepping in and doing something special. I think it ought to be very much the exception.

Senator **Trible**. Would you agree, Dr. Bartlett?

Dr. **Bartlett**. One of the strengths of the system is that it is a little chaotic in the sense that you have a variety of agencies coming at the problem with quite different purposes. And that, it seems to me, is very desirable. It suggests that probably we are not talking about something that can be planned from the top down.

On the other hand, neither is it a system that is wholly chaotic. There is a good deal of feedback that is going on all the time that helps to—and this point was made earlier this afternoon—inform the National Science Board, people who are setting budgets within the Foundation for the various agencies of the Federal Government that support research so that people are trying to lean in some ways that set some priorities and that establish some emphases, but they are never overwhelming emphases.

It seems to me it is that interactive process between actual experience and interest of investigators on the one hand, and the concerns of administrators on the other, both in a sense the pragmatic side of it and the fact that an annual budget has to be put together which, by definition, requires some priority decisions, that makes the system very good.

If I were asked whether I wanted the whole Federal support of science in the U.S. Government to be simply the NSF writ large, I would be a little worried. But the system without what NSF does and the way it operates would be enormously impoverished.

Senator **Trible**. Dr. Branscomb?

Dr. **Branscomb**. I would like to suggest that the National Science Board was created the way it was for a very good reason by the Congress and the President, and it represents an effort to institutionalize that problem of priority selection at a place that is both close to the investigator community, because that is where the board members are drawn from by law and by tradition, and also is a place where these budget tradeoffs have to be made because a budget does have to be put together.

I would suggest to you that there are some kinds of decisions that must be made from the top down because not to do so makes no decision at all. A very large telescope, an oceanographic drill ship, a major international project like the IGY, simply must be organized, planned, and justified.

But our scientific community has good experience now at doing that, and in fact, it is quite remarkable the extent to which the major big science projects are the result of the agency, like NSF, going back to the community and saying, you folks get together outside the Government and debate among yourselves what is the single most important thing for your science in the way of large facilities for the next 5 years. And in almost every case, that has been the project that has gone forward eventually.

A final comment I would make is that the board frequently is well aware of a field that is grossly underfunded in the sense that our scientific conviction is that if this field were substantially larger and more robust, the economic and social benefits to the people would be great, or at least we would have a good chance of its being great.

Plant biology is one of our fields that we feel that way about now and have felt that way for about 3 years. And it is getting priority and expansion. But you will find the Science Board also engaging in a debate when the issue of expanding plant biology comes up, which is how well will the money be spent if it is increased above a certain rate.

And the Science Foundation is, to its credit, very reluctant to throw money at fields to the point where there is not the talent there to respond with intellectually competitive proposals, competitive with all the rest of science. And that is a chicken and egg problem that we struggle with all the time. It is an undefended field; there are not enough investigators, enough university centers. It does need a little extra, but that is a cautious process. That priming, if I may call it that, is a cautious process in the hands of the Board and we usually do not yield to the temptation to try to force intellectual progress at a more rapid rate than good people can make it.

We have, by the way, the same problem in industry. Very often in my company there will be an area in which we desperately need scientific progress. We will turn to our research laboratory and say why don't you put a big project together and work on that now, fast. The answer comes back—we will; as soon as we have a good idea we will let you know. And genuinely, they do not spend the money until they have a good idea.

Senator **Trible**. Let me ask you this question in conclusion, and I appreciate your patience today with the democratic process and your willingness to take so much time and make this contribution.

You represent industry and the academic community. What is the appropriate responsibility of industry, government, and the universities to support basic research? What would the role be if you could craft it in an ideal sense?

Dr. **Kennedy**. I will take a beginning crack at that. As I see it developing over the next 10 years, I do see that the new set of relationships will probably stimulate a modest increase in the incremental support associated with the private sector. I think that will be very modest.

And I think that the driving force of the law that Frank Press mentioned that causes each unit of new discovery to be more expensive than the last will produce a situation in which the public sector obligation to fundamental research increases rather than growing, alas, as the profit sector's interest increases.

My best guess is that it is going to take at least as much proportionate public investment as it has in order to do the thing right. I just do not see it likely that there will be significant substitution or, indeed, that there can be.

Dr. **Penzias**. I do not disagree with that.

Dr. **Branscomb**. I think the Federal Government is obviously the primary responsible institution for the financing of basic research, even though companies—and Bell Labs is famous for it—have contributed very importantly in basic research and will continue to do so.

The magnitude of that investment needs to be set, in my view, by two initial notions. One is Dr. Keyworth's description of the status of many of our university laboratories as shabby. Those are strong words, but I think they are appropriate in many examples; certainly not across the board. There are not very many shabby laboratories in his university, but they do exist.

Therefore, I think there is a significant increase in investment in basic research in universities that is needed simply to make the current capability operate at an efficient, an optimally efficient level.

Second, I think the industry involvement with the universities should be viewed from two perspectives, and neither of these really involves the amount of money that is transported through that mechanism, which I agree is modest compared to the total and always will be.

The first is that the university-industry relationship, if it is healthy, should give you gentlemen confidence that if you follow the strategy of investing Federal money in the universities, the benefits will flow out of the private sector to the public. The mechanism is complicated, and you cannot guarantee your constituents that a dollar spent at Stanford or the University of Alabama is going to show up in a job in San Diego or in Birmingham. But that mechanism is the mechanism, and if it is healthy, that is the important issue.

There is another reason why the university-industry mechanism needs to be healthy. If it is healthy, then the university investigators in their own initiation of proposals to the Science Foundation in the mode that Dr. Penzias describes, will reflect the appropriate degree of interest that they have in the problems that industry has.

So if we are going to ask the question—I happen to be very interested in ceramics technology because it is very important in our industry. And if you put me as boss of the universe I might tell the universities to do more work in ceramics, but that is not the way to do it. The way to do it is to give enough good applied materials scientists or materials engineers in universities contact with those ceramic problems in industry and contact with the basic research ceramic departments. They make an informed judgment and then the NSF and the other agencies will receive proposals from a person who already knows why he wants to do this work, and who it will be helpful to in the broad framework.

So, to recapitulate, the industry involvement is really one that should exert a healthy natural force on the universities' own interests and motivations, and it is the mechanism through which we can more rapidly deliver the public benefit, the fruits of this public investment.

Dr. **BARTLETT**. I think Don Kennedy and Lewis Branscomb have just identified the two essential ingredients that respond to your question. And I would just like to underline the characteristics in that combination.

The funding mechanism needs to be understood in one way. The set of human interactions in another. And both of those are part of the support system by which we get to where we want to go. And one of the most important things that is happening, I believe—and it has not been going on long enough for us to be sure, but I believe it is happening—is a great deal more enrichment of the interaction between universities and industry on a personal level; not in terms of funding. We are not going to get a new world built in our laboratories as a result of funding from industry.

But the human interaction of people actually working together begins to do what Dr. Branscomb was describing, which is to identify problems to each other, to build common interests, to insure transfer of technology. Indeed, one of the things that is most important in this relationship would be the extent to which we can involve our graduate students in industrial laboratories. We can make engineering much more immediate, and we have some real lessons to learn from the Germans in that regard in our engineering education.

It is that human interaction which is part of the resource that we need to build upon. This type of interaction is one of the contributions, if you like, that industry can make to science and universities, and that science and universities can make to industry. And that may be more important than any funding relationship because my guess is the funding relationship that has been built up over the last 30 years is not going fundamentally to be altered. State governments or the State universities providing certain essential resources, the Federal Government being the principal supporter of basic research, the universities being the agency by which research and training is tied together will continue.

That mechanism is so big and so well established that I think it would be very unlikely that we will fundamentally change it in the near future, or should we. It seems to me it is a success as a conception.

Senator **Trible**. Gentlemen, on that note, perhaps we should close these proceedings. I thank you for your contribution today. The proceedings of this session will be available to our absent colleagues. We will all benefit by your statements and remarks today. Thank you very much.

[Whereupon, at 3:45 p.m., the subcommittee meeting was adjourned.]

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